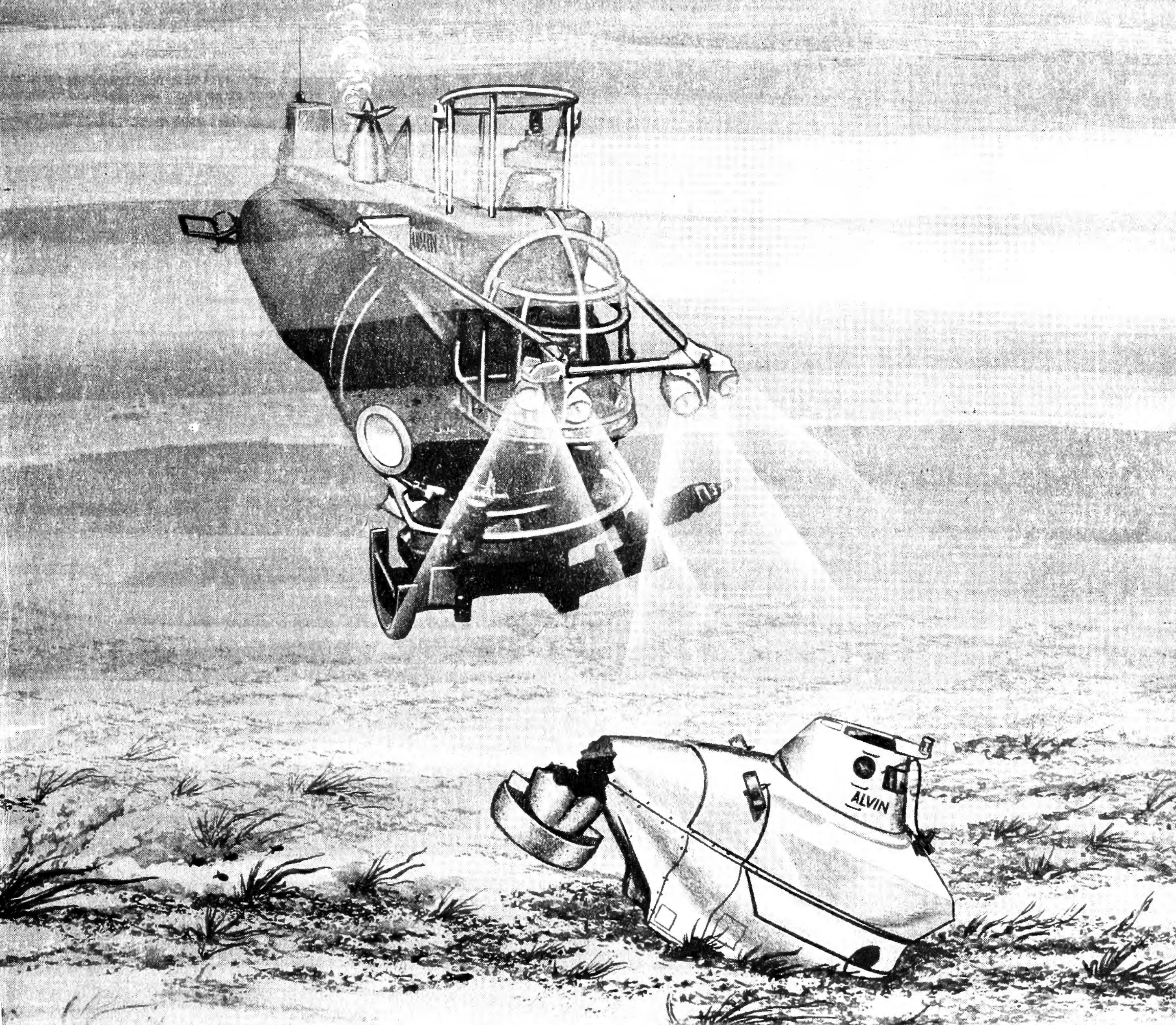
RECOVERY OF DEEP RESEARCH VEHICLE ALVIN

NAVSHIPS 0994-004-5010



DEPARTMENT OF THE NAVY
NAVAL SHIP SYSTEMS COMMAND
WASHINGTON, D. C.

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DECEMBER 1969

This technical report prepared for the Supervisor of Salvage, Naval Ship Systems Command, by Potomac Research, Incorporated.

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NAVAL SHIP SYSTEMS COMMAND
WASHINGTON, D. C. 20360

FOREWORD

The recovery of the Deep Research Vehicle ALVIN from a water depth of over 5,000 feet has several extremely significant aspects. First, and foremost, is that no recovery of an object of ALVIN's size from such a great depth had ever been achieved, although the operation was conceivably within the state-of-the-art. Second, the development of lift line data played a key role in the recovery operations. Undeveloped until this time, this data is expected to play a vital role in enabling the Navy to understand the relationship of dynamic loading to total loading in the recovery of heavy objects from great depths. A third important aspect of this operation was the use for the first time of a single piece of very long nylon line, the behavior of which was not easily predictable, to lift a heavy object.

The ALVIN recovery operations again emphasized that no task in which work in the deep ocean is performed should be considered routine. The success of this operation is attributed to the technical expertise and initiative shown by the recovery force personnel, composed of representatives of the Naval Research Laboratory, Office of Naval Research, Submarine Development Group One, Supervisor of Salvage, Military Sea Transportation Service, Woods Hole Oceanographic Institution, Naval Underwater Weapons Research and Engineering Station (Newport), and Ocean Systems, Incorporated. Of particular note is the cooperation, initiative, and excellence of seamanship displayed by the crew of USNS MIZAR, and the work performed by the crew of the Deep Research Vehicle ALUMINAUT. The ALUMINAUT crew's ultimate success in the arduous task of affixing a toggle to ALVIN for the lift was a key factor in enabling the On-Scene Commander to carry out the recovery plan. Recognition must also be given to those personnel

who supported the recovery force by contributing their skills, determination, and many hours of effort to detailed planning, shipyard work, and testing of systems. The task of coordinating the diverse elements and positively directing the operation cannot be minimized. It was done with great effectiveness under the inspired leadership of Lieutenant Commander William I. Milwee, Jr., USN.

This report has been prepared under the direction of the Supervisor of Salvage, U.S. Navy. The intent of the report is to fully document the procedures employed and the experiences encountered during ALVIN recovery operations so that in the future deep recovery salvors may profit from the information.

E. B. MITCHELL
Captain, USN
Supervisor of Salvage, U.S. Navy

ABSTRACT

On 16 October 1968, the Deep Research Vehicle ALVIN was lost in 5,051 feet of water off the coast of Cape Cod, Massachusetts. At the time of her loss, ALVIN, owned by the U.S. Navy and operated as an item of Government Furnished Equipment by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, had successfully completed 307 dives since being put into operation in 1964. ALVIN gained international fame in 1966 when she located and helped retrieve a hydrogen weapon lost off the coast of Spain. This 15-ton, 23-foot manned submersible, representing a 1.5 million dollar investment, is one of the few Deep Research Vehicles capable of 6,000-foot diving depths. These factors were important considerations in the decision to recover her. Although the basic operational plan for her salvage was considered feasible, recovery attempts in October and November of 1968 were unsuccessful due mainly to unfavorable weather conditions. The recovery of ALVIN was postponed until August 1969, when weather was more favorable. ALVIN was successfully raised on 1 September 1969.

This was a unique operation since recovery of objects of this size from this depth had never been accomplished previously. The recovery of ALVIN represents a major step forward in the Navy's ability to conduct deep ocean engineering operations. The success of this salvage operation, which was under the direction of Lieutenant Commander William I. Milwee, Jr., USN, assigned from the Office of the Supervisor of Salvage, U.S. Navy, is attributable to the careful and thorough planning and preparation by all activities involved.

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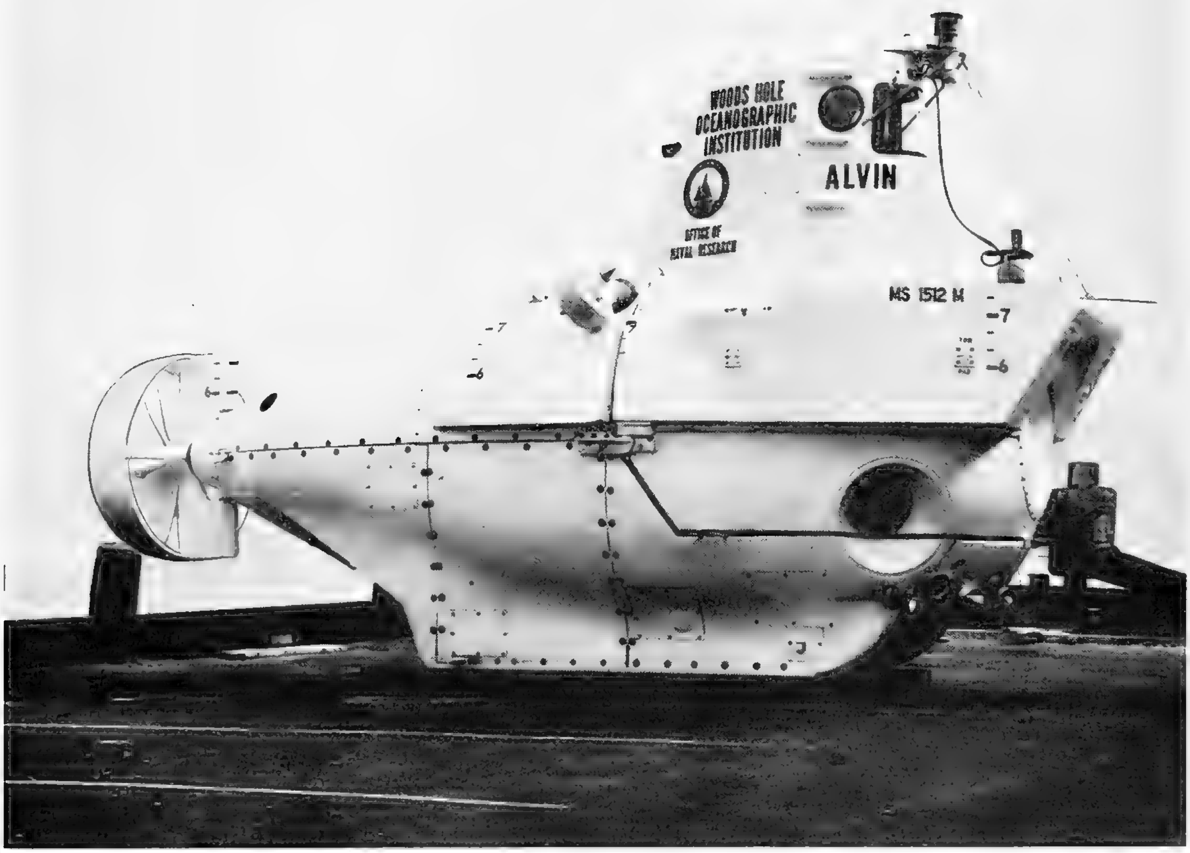

Frontispiece. Deep Research Vehicle ALVIN.

INTRODUCTION

This report on the recovery of the Deep Research Vehicle (DRV) ALVIN has been prepared to provide a permanent record of the salvage operations, emphasizing the techniques developed and the lessons learned. Basically, the concept for this recovery operation was simple. However, it must be remembered that the recovery of an object of this size from a depth in excess of 5,000 feet had never been accomplished previously. Planning and executing such an operation required flexibility and the development of alternative approaches to each phase.

The execution of certain elements of this operation involved complex techniques and operational factors such as:

Lift ship selection
Submersible selection
Lift device design
Precision navigating and positioning
Attachment of lifting line to ALVIN
Long line lift from great depth
Submerged tow techniques.

Additionally, the success of any operational plan was to some extent dependent upon favorable weather conditions.

The main body of this report is a chronological narrative of the salvage operation. Supporting data have been included in Appendices A through I. Photographs and diagrams have been used throughout to support descriptions and details of the salvage operation.

BACKGROUND

During October 1968, a task force consisting of the catamaran Research Vessel (R/V) LULU, with ALVIN aboard, and the R/V GOSNOLD departed Woods Hole, Massachusetts, for at-sea operations.

On 16 October 1968, ALVIN, with her three-man crew, was being launched from LULU to make a routine inspection of buoy moorings off the coast of Cape Cod. The moorings

were located in over 5,000 feet of water approximately 10 miles west of Hydrographer Canyon.

ALVIN was being lowered over the side when two steel cables on the launch cradle of LULU snapped, causing ALVIN to plunge forward into the water. As ALVIN plunged into the water, LULU's crew members held on to heavy nylon retaining lines, which had been attached to the side of ALVIN during launching. Simultaneously, LULU's captain moved the catamaran forward providing clearance for the three-man crew inside ALVIN. ALVIN sank below the surface and popped up again allowing the three men inside to scramble safely out onto the side of LULU. ALVIN was down by the bow and flooding rapidly through a broken forward observation window in her conning tower (figure 1), thence through an open pressure sphere hatch. The retaining lines snapped, and the 15-ton submersible plunged to the ocean floor. GOSNOLD and LULU remained at the scene for 2 days following the accident. They made a careful survey of the area and narrowed the search site to 1 square mile. ALVIN's position was estimated as latitude 39°53.5' N and longitude 69°15.5' W. (Refer to Appendix A, figure A-1, a chart of the loss area.)

The extent of damage sustained during the mishap could not be fully known until ALVIN was found and raised. However, ALVIN's stern propeller was observed to have been knocked off during the accident, and it was felt that there might have been other damage to the stern area, which encloses the trim tanks, buoyancy controls, and the steering propulsion mechanism.

Salt water damage to the instrumentation in the pressure sphere was expected to be extensive. The depth to which ALVIN had sunk was not a factor in estimating damage, as she was capable of dives to 6,000 feet. (For detailed vessel characteristics, refer to Appendix B.) The bottom was thought to be firm clay covered by silt, and impact damage would depend on the exact angle and speed with which she hit bottom. The consensus was that she dropped at a speed of approximately 10 knots, at a 45° to 60° nose-down angle, and with hatch open.

An operation to recover ALVIN was initiated immediately. The DRV DOWB and R/V CHAIN were used; however, difficulties with DOWB and the onset of North Atlantic winter caused the operation to be terminated on 23 November 1968.

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In the ensuing months, further consideration was given to the recovery of ALVIN. The following factors were considered adequate to justify planning a salvage operation for 1969:

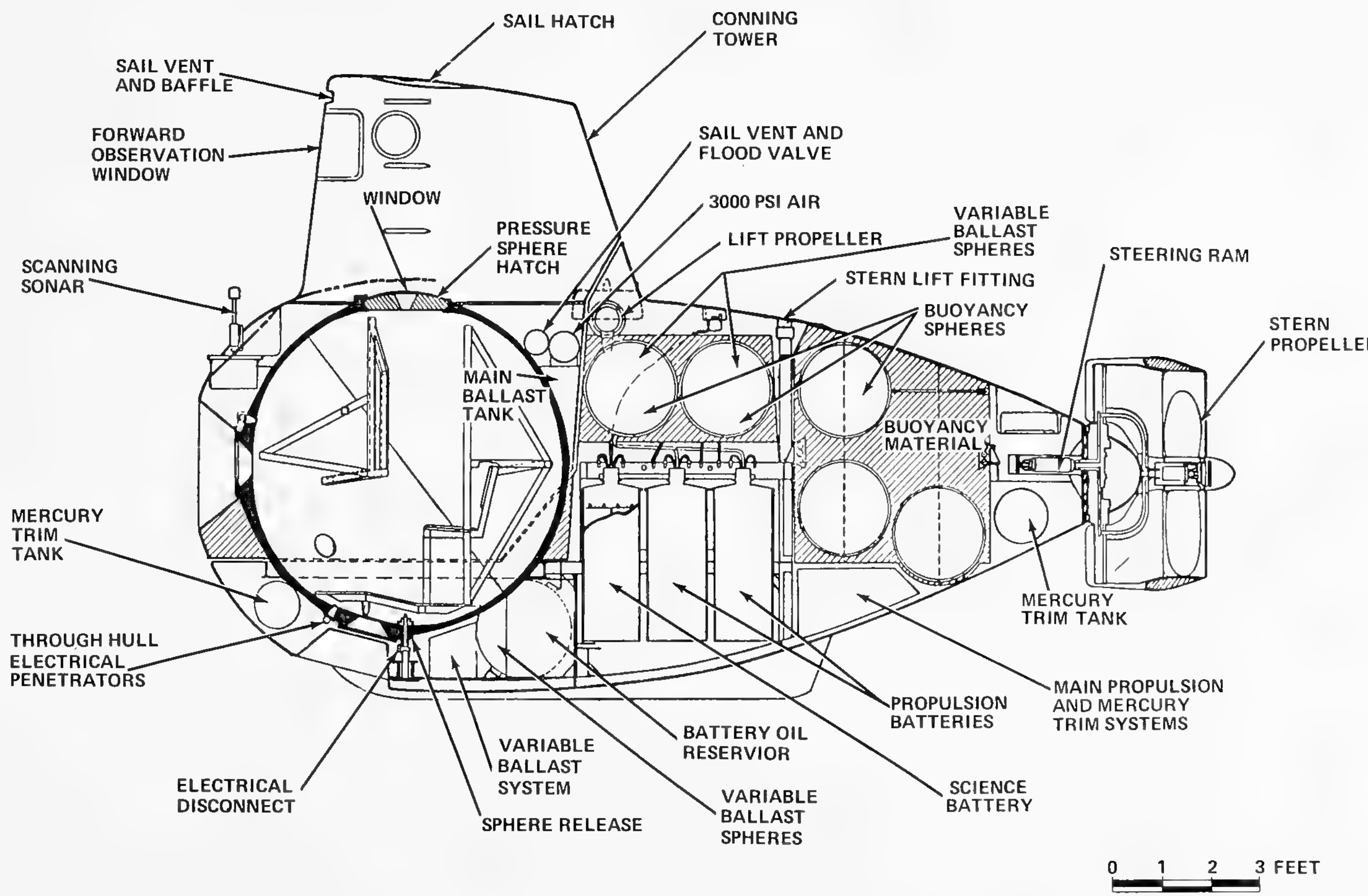


Figure 1. Cross Section of ALVIN.

1. The salvage value of this highly successful submersible would far exceed the anticipated cost of any recovery operation.

2. While such a recovery was considered within the state-of-the-art, no recovery of an object this size from such great depths had ever been achieved. A practical deep ocean operation such as this could prove the technologies and techniques involved and reveal any deficiencies.

3. Studies conducted subsequent to the recovery would provide otherwise unobtainable information on materials behavior in a deep ocean environment.

FORMULATION OF SALVAGE PLANS

LOCATING OF ALVIN

On 10 June 1969, ALVIN was found and photographed by a towed sled of the USNS MIZAR (T-AGOR-11), a research vessel operated by the Military Sea Transportation Service for the Naval Research Laboratory. The location of ALVIN was determined as latitude $39^{\circ}52.2'$ N and longitude $69^{\circ}11.5'$ W, approximately 88 miles southeast of Nantucket Island and 135 miles from Woods Hole. (Refer to Appendix A, figure A-1.)

ALVIN was found to be upright with her bow down about 10° to 15°, resting in approximately 2 to 3 feet of soft, silty mud. The sail hatch was open (figure 2), but it was not possible to determine from the photographs that were taken if the pressure sphere hatch was open. The pressure sphere hatch, which was spring loaded to remain open and restrained by elastic cord, had been open when ALVIN went down; it was probable, therefore, that it was still open unless the force of impact with the bottom caused it to close. Except for the stern propeller and shroud, torn loose by contact with LULU at the time of the casualty, ALVIN appeared to be intact.

BASIC SALVAGE CONSIDERATIONS

After location of ALVIN by MIZAR, conferences were conducted during June and July 1969 to formulate salvage plans. Representatives from the Office of the Supervisor of Salvage, U.S. Navy (SUPSALV); Office of Naval Research (ONR); Naval Material Command (NAVMAT); Naval Ship Systems Command (NAVSHIPS); Naval Ship Engineering Center (NAVSEC); Woods Hole Oceanographic Institution (WHOI); and Ocean Systems, Inc. (OSI) met to review numerous recovery plans and to determine which was best suited for the ALVIN

Figure 2. Top View of ALVIN on Ocean Floor.

recovery. Also, equipment lists were developed, ships and craft to be assigned to the recovery force were recommended, and modifications required for each of these vessels were determined.

Initial Concepts

The basic recovery concept was to (1) relocate ALVIN; (2) attach a lifting line with the assistance of either an unmanned tethered device or a manned deep research vehicle; (3) winch ALVIN to the surface with a lift ship; and (4) tow her to port or into shallow water for lifting from the water. Careful consideration was given a number of factors that would bear significantly on the recovery attempt. For example, the date of the recovery operation would be dependent upon weather conditions. (The unsuccessful salvage attempt of November 1968 had emphasized that the weather would be a major factor in the salvage attempt. From past weather history, it was determined that the most favorable weather could be expected during July, August, and September.) Also, the water depth and lift weight would dictate the type of lift line, the recovery device, the surface support ship, and the lift ship that could be used.

The weight of ALVIN was carefully considered. Recovery of objects of this size from such a depth had not been accomplished previously. ALVIN, with a weight of 31,500 pounds in air, was estimated to weigh 8,800 pounds in water with the sphere flooded, assuming that the syntactic foam was still fully effective. Syntactic foam is known to suffer water permeation during long exposures at elevated pressure. There was neither experience nor data available on the effects of submergence at this depth for such a long period; accordingly, the loss of buoyancy could not be accurately estimated. If the entire syntactic buoyancy of 9,300 pounds had been lost, the in-water weight would be increased to 18,100 pounds. Complete loss of buoyancy imparted by the syntactic was not, however, considered probable; the anticipated loss was expected to be 30 percent or less.

An additional factor affecting the lift was bottom breakout. Breakout forces were expected to be as high as 25 percent of the in-water weight of ALVIN. Since these forces are dependent upon the time period over which the force is applied, it was estimated that the breakout force could be reduced to about 10 percent of the in-water weight if a gradual breakout was effected.

In consideration of the depth and lift weights involved, a single piece of 4 1/2-inch Columbian double-braided nylon line with a nominal length of 7,000 feet and a breaking strength of 53,000 pounds was selected as the primary lift line. Two back-up lift lines would also be provided, one of 4 1/2-inch double-braided Samson nylon and the other of 8-inch polypropylene. (A complete listing of the equipment used during the ALVIN salvage operations is given in Appendix C.)

Lift Line Attachments

Potential methods for attachment of the lift line to ALVIN were evaluated with respect to operational requirements and cost factors.

Tethered Devices. Three tethered devices were available for consideration; two of these, however, did not meet the depth requirements and would present positioning and maneuvering problems. Conversion and testing of these two devices would require unwarranted expenditures of time and money. The third available tethered device, CURV, met the depth requirements; however, she had one disadvantage in that she could not take the recovery line down to ALVIN, but rather must rely on surface placement in the vicinity of ALVIN.

Manned Submersibles. Three manned submersibles were considered for this operation, DEEP QUEST, DOWB, and ALUMINAUT. DEEP QUEST was ruled out, as it is mandatory that her support platform, the TRANSQUEST, be used at all times. This would present prohibitive transit time and costs from her home port of San Diego to the East Coast. DOWB, used during the 1968 ALVIN salvage operations, was considered too vulnerable during launch

and recovery, even considering the use of support platforms with special handling systems. Also, DOWB's optical viewing system had encountered difficulties during past operations of this nature.

The third submersible considered for use as the recovery device, and the one finally selected, was the DRV ALUMINAUT, owned by Reynolds Submarine Service Corporation, Miami, Florida. She had the capability of performing the entire operation essentially as a self-contained unit, being capable of carrying the recovery line to the bottom and attaching the line with her two manipulators. In addition, she was available for immediate operations.

Command and Support Ships

Command Ship. MIZAR offered unique advantages for a command and lift ship for ALVIN. She was equipped with computerized facilities for accurate navigating and tracking from prepositioned transponders. Her large, stable platform could accommodate a 50,000-pound-pull traction winch, and she could handle a large lift line. The ship could provide tie-down points for additional safety harnesses, nets, and straps placed on ALVIN once she had been raised to near the surface. Additionally, the ship could lift either over-the-side or through its center well.

Support Ship. The offshore supply boat M/V STACEY TIDE was selected as the support ship to tend ALUMINAUT, to track her position underwater, and to maintain position relative to a bottom transponder/pinger, which marked ALVIN's position.

Lift Line Stress Considerations

Dynamic response and stress calculations (detailed in Appendix D) indicated that lifting over the U-frame on the starboard side of MIZAR, as was initially proposed, would result in lift line stresses exceeding breaking strength, particularly at very short line lengths. The analyses, performed by the Naval Research Laboratory (NRL) and NAVSEC, revealed that lifting through the center well would eliminate the effects of ship roll and pitch, which would reduce lift line resonances to well below the critical point.

SALVAGE PLANS

After careful consideration of the aforementioned factors, the decision was made to conduct the recovery of ALVIN during August 1969.

On 6 August 1969, the Chief of Naval Research tasked SUPSALV with the responsibility for the recovery of ALVIN. Lieutenant Commander William I. Milwee, Jr., USN, from

SUPSALV, was assigned over-all project responsibility. Prime contract assistance was provided by Ocean Systems, Incorporated.

The units in the assigned recovery force and their primary functions were as follows:

Afloat Units

USNS MIZAR	Command ship, relocating, computer ranging and tracking, and salvage lift.
DRV ALUMINAUT	Under contract to OSI to provide on-site search, physical investigations, and to act as a self-contained system for lift toggle insertion complete with lift line.
M/V STACEY TIDE	Support ship for ALUMINAUT and secondary plotting, tracking, and underwater communication center.
R/V CRAWFORD	Provide extra accommodations, and back-up plotting and underwater telephone communications.

Support Activities

Boston Naval Shipyard	Initial staging base. Provide industrial support to accomplish fabrication and installation of lifting gear and deck arrangement on MIZAR under direction of on-scene SUPSALV representative.
Woods Hole Oceanographic Institution	Furnish R/V CRAWFORD, plotting and recording personnel, and requested support services to on-scene SUPSALV representative. Also, function as communications and logistics base and public affairs center.

Salvage correspondence, and a listing of personnel and activities involved in the salvage operation, are given in Appendices E and F, respectively.

It was imperative that each step of the salvage operation be carefully planned. A detailed preliminary plan was developed, supplemented by a number of alternative actions. Of partic-

ular importance in making recovery plans was whether ALVIN's sail hatch was open or closed, and if closed, whether it could be opened. Although MIZAR had previously located and photographed ALVIN in June 1969, and the pictures showed ALVIN's sail hatch open, it could not be determined if the pressure hatch was open.

SUPSALV's detailed plan for recovering ALVIN consisted basically of the following steps:

1. Relocating and marking
2. Attachment of lift line
3. Lift to surface
4. Diver survey and attachment of safety lines
5. Tow to shallow water
6. Final lift and salvage.

1. Relocating and Marking. MIZAR would return to the site where she had located ALVIN in June 1969, relocate ALVIN, drop a transponder to mark datum, and then proceed to Boston Naval Shipyard for outfitting. Upon receipt of a favorable weather forecast, the ships, with ALUMINAUT under tow by her support ship, would get underway for the recovery site. MIZAR would return to the site, position herself over ALVIN using the transponder as reference, and maintain station.

Upon arrival on-site, ALUMINAUT would receive the lift line, lifting bridle with attaching devices, an AMF transponder, and a hatch opening device. The lift line, wound on a reel, would be mounted on special brackets mounted on ALUMINAUT's bow.

ALUMINAUT would make a test dive to check out all systems. If all was satisfactory, she would continue her descent. MIZAR would interrogate the AMF transponders on the bottom and on ALUMINAUT using a frequency of 16 kHz, and both transponders would answer on 10 kHz. Utilizing a tracking computer, the tracking and plotting team would vector ALUMINAUT to the transponders. Once ALUMINAUT was on the bottom, it was planned that she would use her Straza sonar to interrogate and home in on a CTFM transponder with a maximum range of 800 yards. ALUMINAUT's CTFM sonar should acquire ALVIN at 500 yards. STACEY TIDE would also track ALUMINAUT.

If the computer did not work, an alternative action would be taken. A second AMF transponder would be put down at a known position relative to the first transponder and, by use of a multiple-range system, the tracking team would be able to compute MIZAR's position relative to the bottom markers. The tracking team would then conn ALUMINAUT to the first transponder until ALUMINAUT acquired the CTFM transponder. ALUMINAUT, when within 500 yards of ALVIN, should then have both ALVIN and the first transponder acquired

on her sonar. (This alternative plan was not used, however, as the primary plan was successful.)

Using bathymetric charts previously made (refer to Appendix A), search navigation was considered to be sufficiently accurate to ensure placing the first transponder on the bottom very close to ALVIN, provided there was no excessive current. Should the transponder not be sufficiently close to ALVIN, ALUMINAUT would move it closer.

Appendix G gives a more detailed account of these navigation plans.

2. Attachment of Lift Line. Once ALVIN was found, a careful inspection would be made and a report given to surface forces. If her sail hatch was found open, or if found closed and successfully opened with either the magnetic device or ALUMINAUT's manipulators, the primary attachment system would consist of a two-legged lifting bridle. Attached to one leg of the bridle was a specially designed toggle for insertion into the pressure sphere hatch. The other leg contained an attaching hook to be fastened to ALVIN's stern lift fitting. The lifting devices are shown in figure 3.

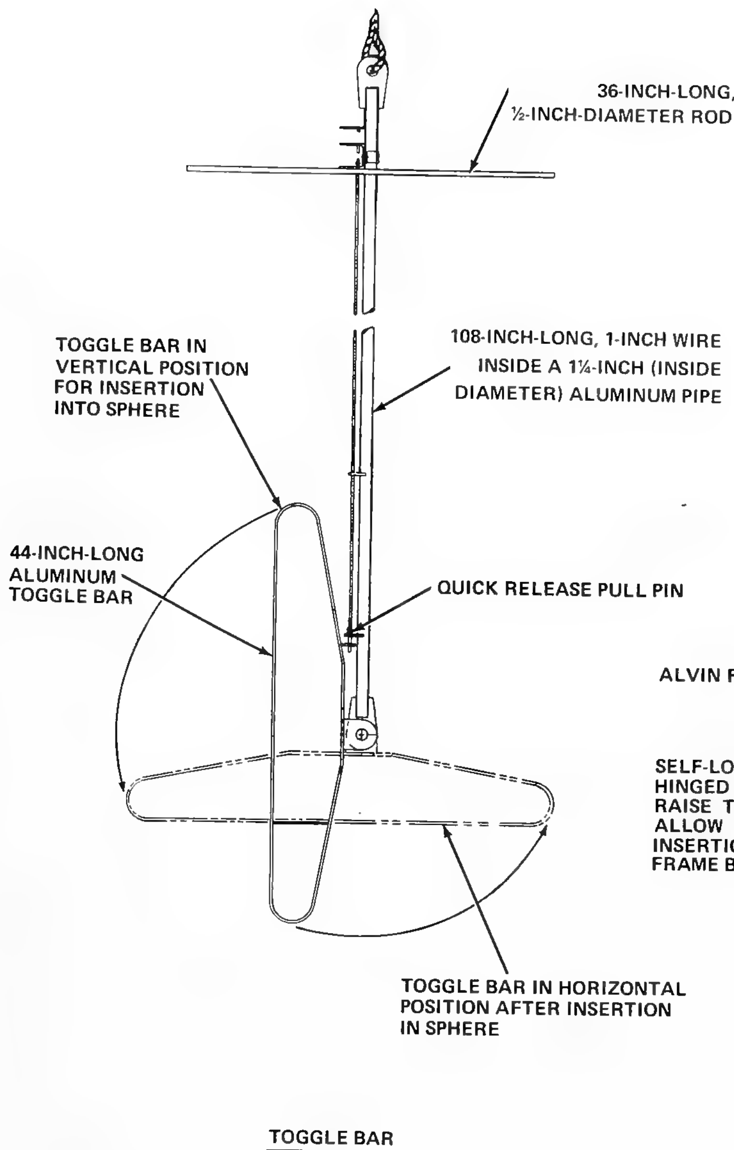
ALUMINAUT would insert the toggle bar through ALVIN's sail and pressure sphere hatches, trip the latch so that the toggle bar would assume a horizontal position inside the sphere, then lock the toggle bar in position so that it would not pull free and so that vertical motion would be held to a minimum. The stern hook on the other leg of the lifting bridle would then be attached to ALVIN's stern lift fitting.

Once the attachment to ALVIN was made, ALUMINAUT would surface slowly, paying out the lift line from the reel. After ALUMINAUT surfaced, the bitter end of the lift line would be transferred to MIZAR for handling and recovery.

Should ALUMINAUT not be successful in attaching the lift line as described above, alternative plans were prepared for both lowering the lift line and for attaching the lift line to ALVIN. The alternative method for lowering the lift line required that the line be transferred to MIZAR for lowering. A full description of this procedure is given in Appendix H. Figure 4 shows the lift line and clump design. ALUMINAUT would then submerge, locate the line and toggle, and insert the toggle for lifting as initially planned.

If ALVIN's sail and pressure sphere hatches were not open, and could not be opened, a nylon line wrapped with canvas chafing gear and weighted with shot would be passed around the bow forward of the pressure sphere and frame, through the lifting pad in the after-body, and then married to the main lift line. Recovery would then proceed as in the primary plan.

3. Lift to Surface. After the lift line had been attached to ALVIN, the bitter end would be rigged through MIZAR's center well and wound onto the traction winch (figure 5). ALUMINAUT would descend again, staying well clear of the line but keeping it in sight.



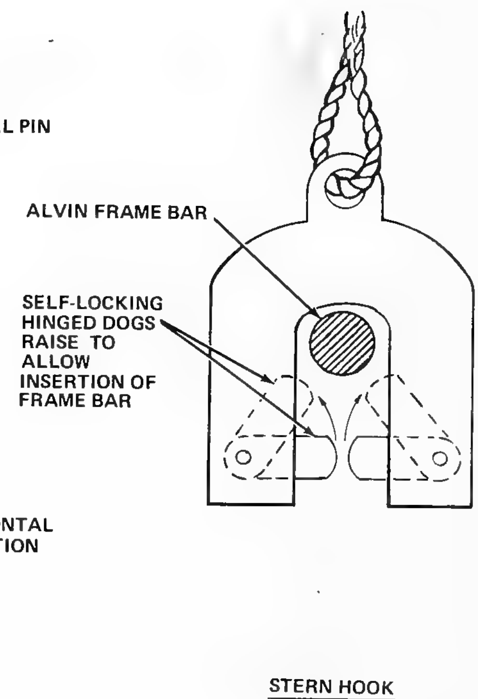


Figure 3. ALVIN Lift Line Attaching Devices.

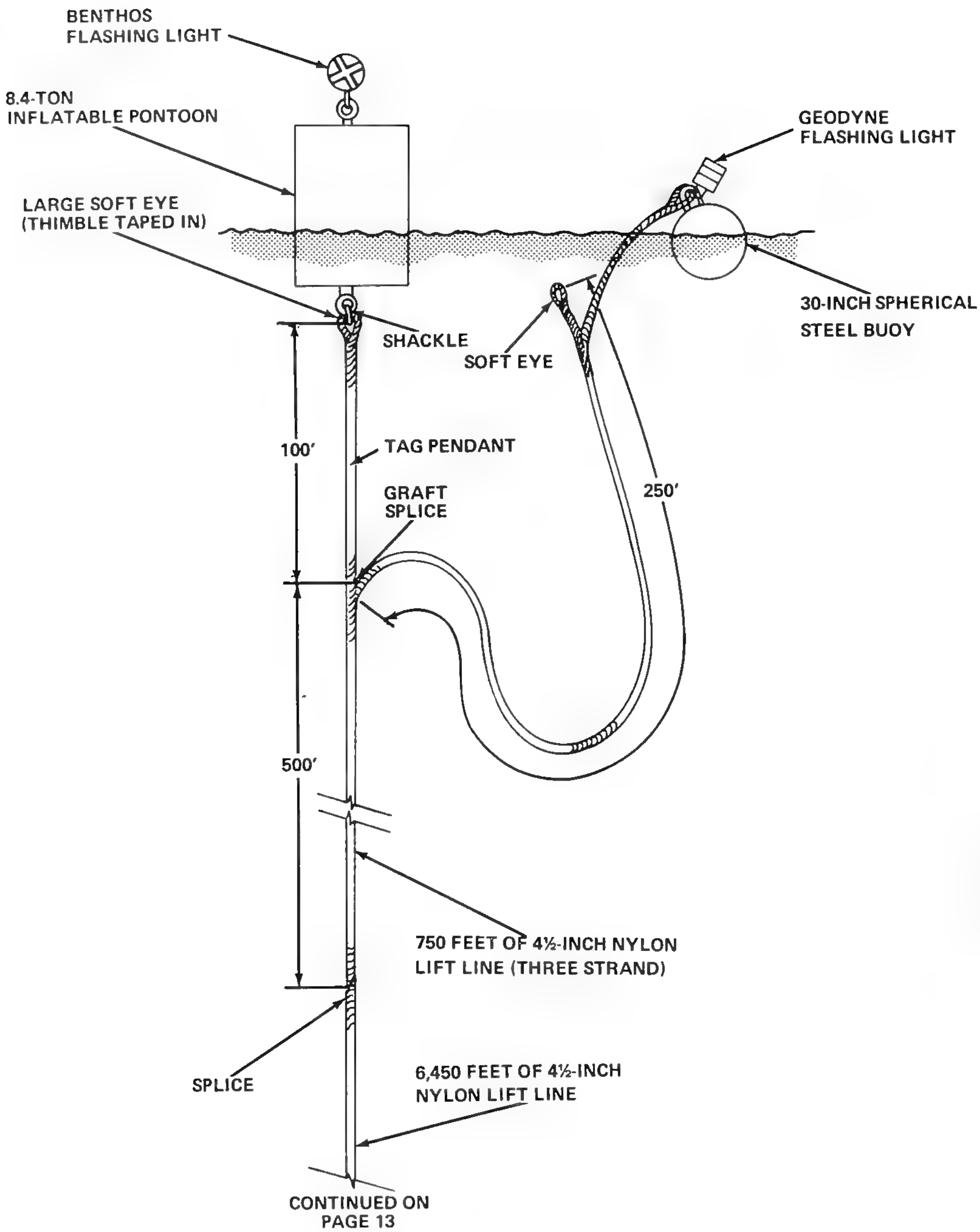


Figure 4. Lift Line for ALVIN Salvage Operations – Upper End.

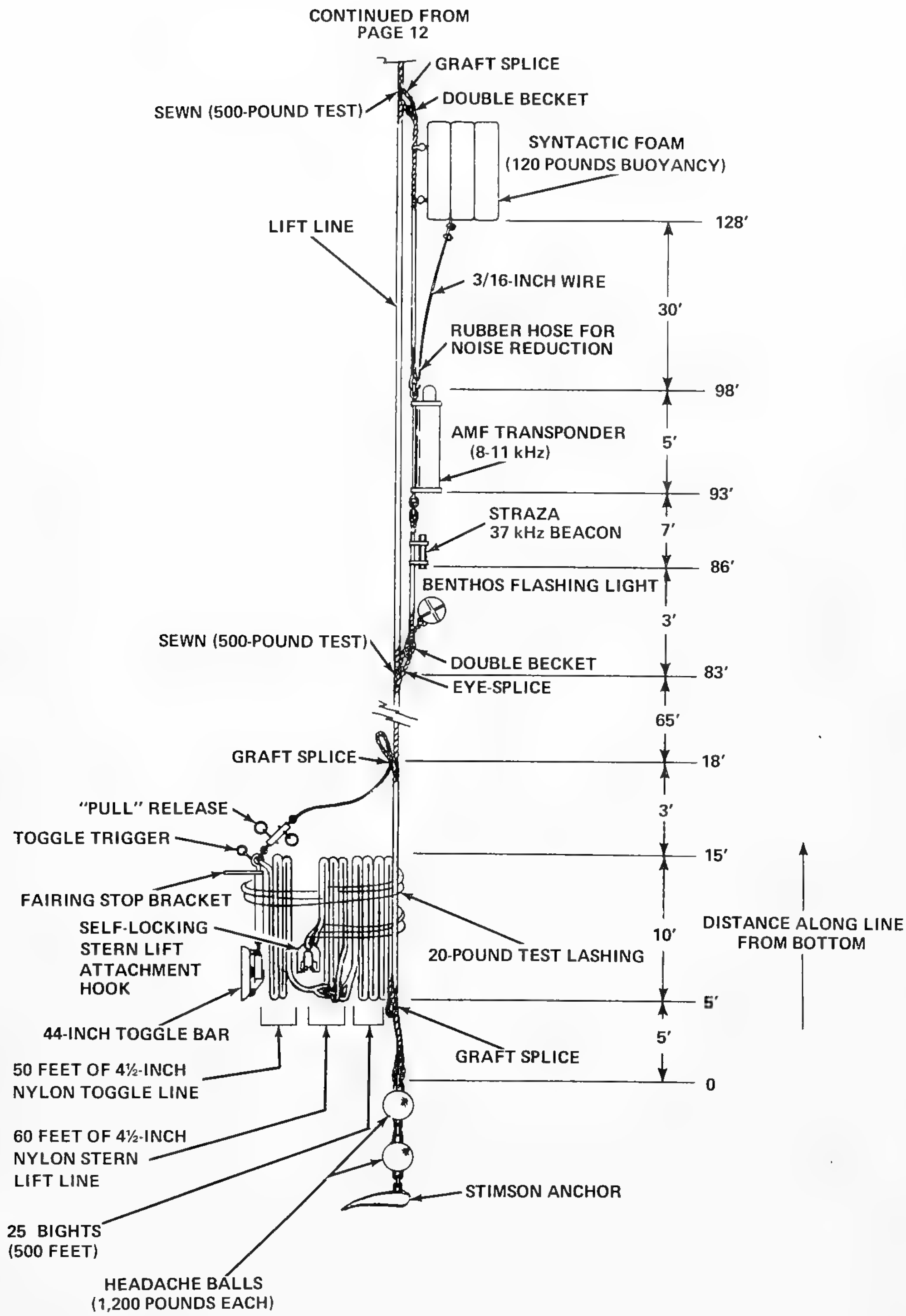


Figure 4 (cont'd). Lift Line for ALVIN Salvage Operations – Lower End.

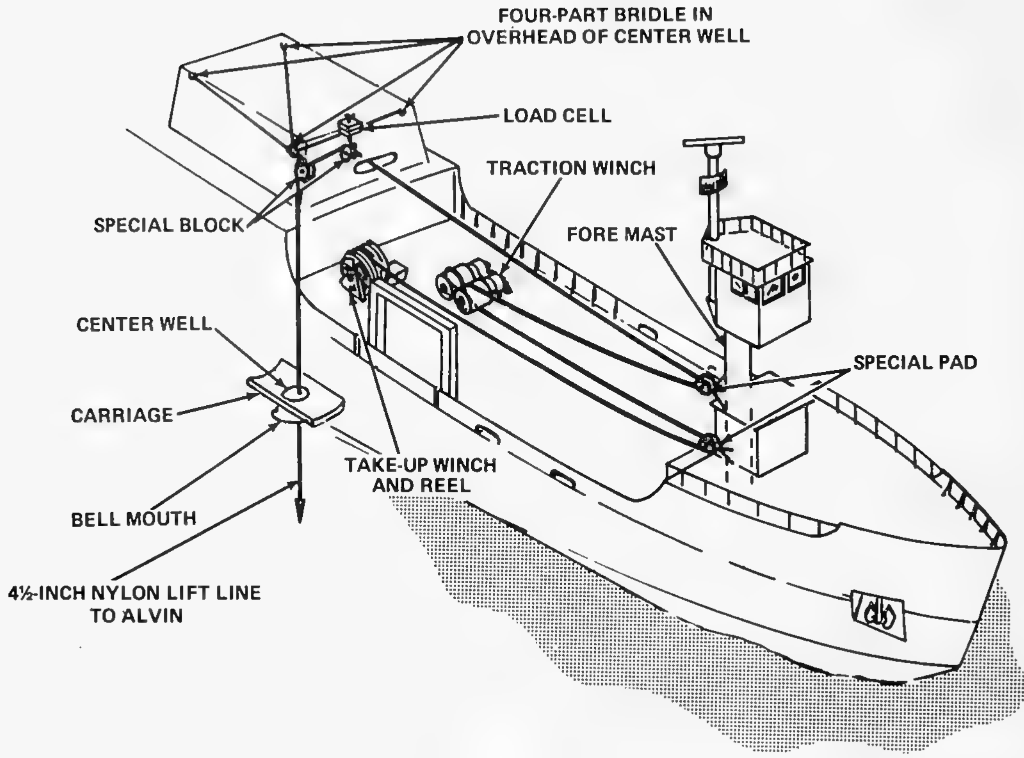


Figure 5. USNS MIZAR's Rigging for Lift of ALVIN.

Once ALUMINAUT had positioned herself clear of ALVIN, and had so reported, the lifting of ALVIN would begin. MIZAR would haul the line in slowly until a steady force of 14,000 pounds was achieved; hauling then would be stopped to allow for a gradual breakout. Once breakout had occurred, ALVIN would be lifted smoothly and continuously at a fixed speed of 35 feet per minute. The dynamometer would be observed at all times and loads recorded every 500 feet. Load surges would also be recorded. The lift line would be marked at 500-foot intervals, and at 100-foot intervals from the lower end to the first 500-foot mark. The final 100 feet would be marked in 10-foot increments.

Conditions permitting, ALVIN would be lifted steadily until the final 10-foot marker was observed. At this point, the lifting would be stopped. ALVIN would then be approximately 50–60 feet below MIZAR.

4. Diver Survey and Attachment of Safety Lines. A team of divers would enter the water, carefully survey ALVIN, and then surface to report their findings.

An 85-foot-long, 1-inch wire pendant, attached to a four-part bridle from the overhead of MIZAR's center well, would then be lowered (figure 6). Divers would shackle the lower

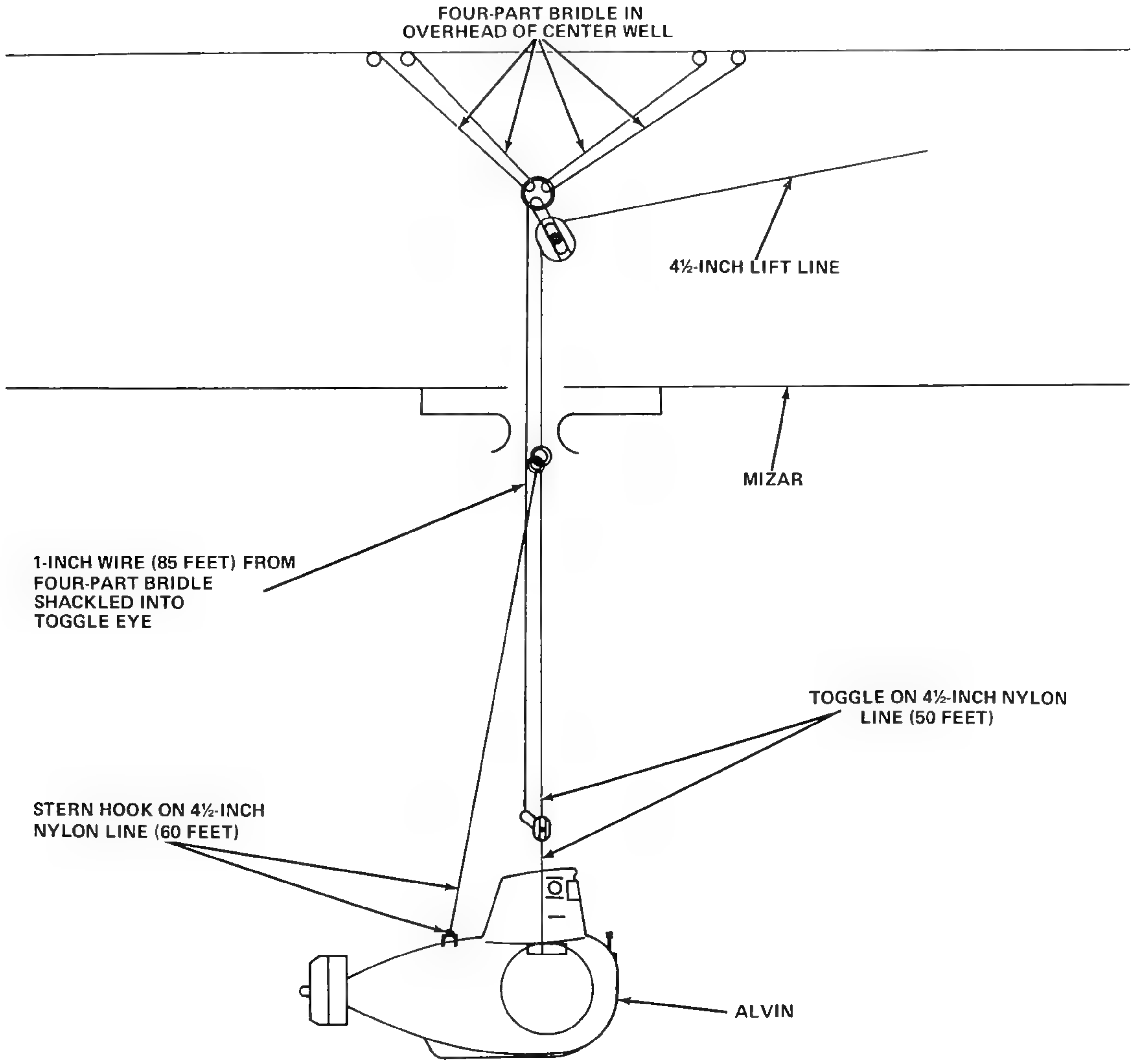


Figure 6. Attachment of Lift and Safety Lines to ALVIN.

end to the ring at the upper end of the toggle in ALVIN's sphere. The 4½-inch lift line would then be payed out slowly until the load had decreased to 5,000 pounds, indicating that the primary support force was exerted by the 1-inch wire.

Actions would then be taken to increase buoyancy and lighten ALVIN. Divers would actuate ALVIN's external solenoids to permit drop-weights to fall free. ALVIN's manipulator arm, released by a trip, and the broken after propeller section, to be freed by divers cutting hydraulic hoses, would be recovered in slings lowered from MIZAR. If possible, ALVIN's ballast spheres would be blown dry.

Safety slings would then be attached to ALVIN. Divers, after removing the cover plates over the personnel sphere cradle, would pass the slings through and around the cradle strong points. The slings would be shackled into stopper lines from the center well.

To ensure relocation should a catastrophic failure occur, a 37 kHz pinger would be strapped to ALVIN. Additionally, as a safety backup and to prevent equipment losses, a prefabricated nylon web net would be wrapped around ALVIN and made fast to the 4½-inch lift line.

ALVIN would then be rigged with a towing bridle from the fore deck of MIZAR in order to maintain proper towing attitude while underway.

5. Tow to Shallow Water. MIZAR, with ALVIN in submerged tow, would proceed at approximately 2 knots towards Nantucket Island. This would gain shallow water along the track (after about 45 hours transit time the water depth would be less than 100 feet). Should the weather "make-up" at anytime during tow, the tow course would be altered at the discretion of the On-Scene Commander to permit ALVIN to be towed to the nearest sheltered point to Woods Hole. Weather and tow conditions permitting, the maximum distance toward shore would be made prior to any "let-go" decision.

Once in shallow water, ALVIN would be set down on the bottom. A lifting rig would be made up using MIZAR's U-frame, and ALVIN would be lifted to the surface. When ALVIN reached the interface the sphere would be dewatered and the ballast blown. She would be placed in a cradle for tow on the surface to Woods Hole.

6. Final Lift and Salvage. Upon arrival in port, it was planned to remove ALVIN's towing rig, then lift her from the water. As the final salvage phase, measures would be taken to prevent corrosion to ALVIN's components. After delivery to her owner, the Office of Naval Research, the restoration process would begin, and a thorough examination would be conducted to determine the effects of submergence upon her systems.

SALVAGE OPERATIONS

MOBILIZATION AND OUTFITTING

Mobilization and outfitting of recovery forces began on 5 August at Boston Naval Shipyard. (Refer also to Appendix I, Outfitting and Testing of Vessels.) Outfitting of units entailed installation and testing of special equipment and gear. ALUMINAUT was outfitted in order to be prepared to dive immediately upon reaching the recovery site. Equipment was tested under simulated at-sea conditions. The completion on 12 August of the static and dynamic load tests of MIZAR's lift system ended the fitting-out period. ALUMINAUT, under tow of STACEY TIDE, departed that evening for bay trials at Provincetown, Massachusetts, and MIZAR sailed for the recovery site to commence search runs.

LIFT ATTEMPT NO. 1

Upon arrival on-site at 0400 on 13 August, MIZAR commenced bathymetric and photographic runs to positively locate ALVIN. A random search pattern was deemed the best method with the highest probability of detection because of the inability of MIZAR to dynamically position her camera-carrying vehicle. The first two camera runs by MIZAR were unsuccessful.

Meanwhile, STACEY TIDE and ALUMINAUT were conducting rehearsals at Provincetown. ALUMINAUT experienced considerable difficulty in handling the lift line and reel during transfer from STACEY TIDE. The addition of a wooden A-frame on the bow of ALUMINAUT greatly facilitated loading of the reel and was believed to be the solution to the handling problem. Figures 7 through 11 show the lift system in operation during the Provincetown trials.

MIZAR continued the underwater search. The third camera run, conducted on 15 August, relocated ALVIN and obtained one photograph. The positive location of ALVIN eliminated the necessity for time consuming and costly searching with ALUMINAUT. MIZAR continued her camera runs until the remainder of the salvage forces arrived on the scene. Photographs obtained during the fourth and fifth camera runs gave no significant additional information, but verified that ALVIN was not embedded in the bottom further than previously thought.

Figure 7. Underwater Photo Showing Lift Line, Reel and Toggle in Place on ALUMINAUT.

Figure 8. Diver Inspecting ALUMINAUT's Manipulators and Lift Line Toggle During Rehearsal.

Figure 9. Underwater View of First Toggle in Position on ALUMINAUT.

Figure 10. Underwater Photo of ALUMINAUT Paying Out Lift Line During Rehearsal.

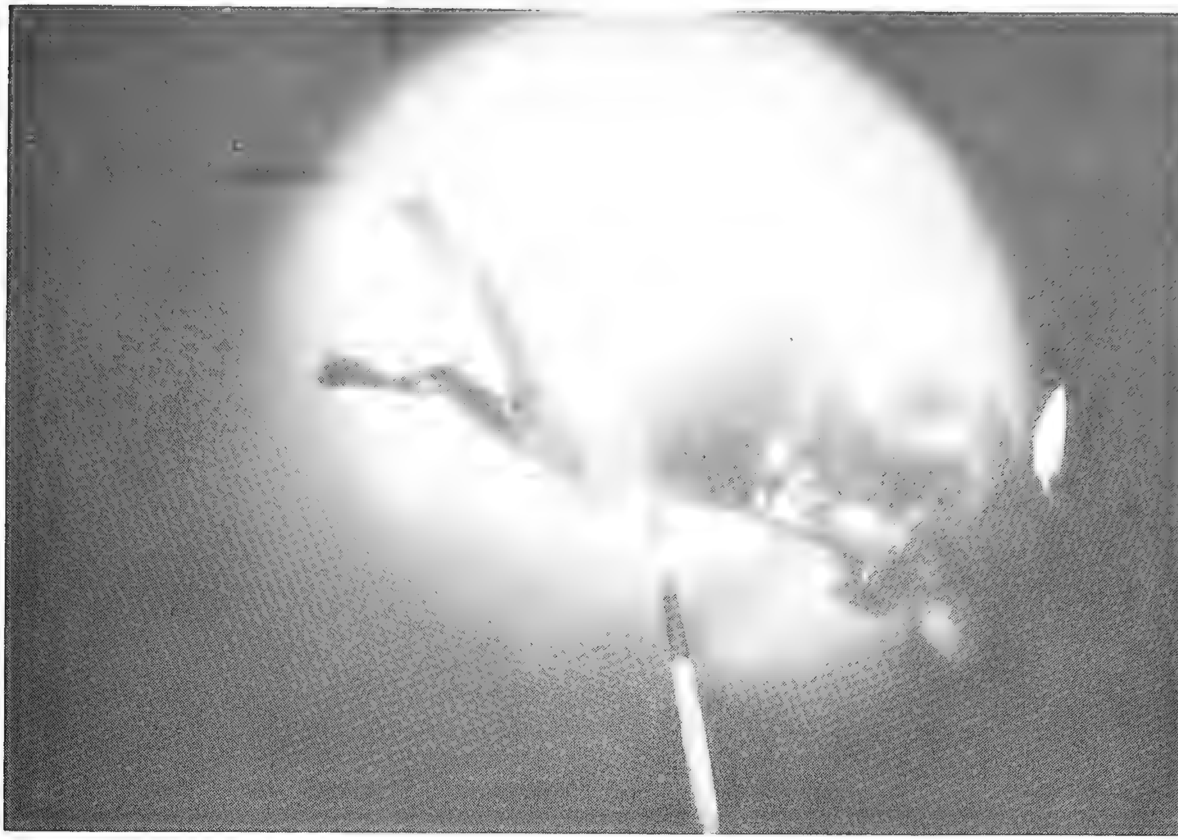


Figure 11. Diver Checking Payout of Lift Line During Rehearsal.

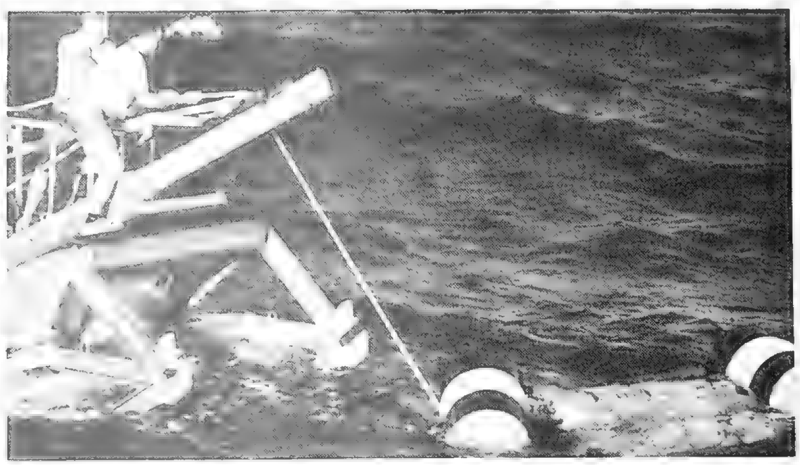
CRAWFORD arrived on scene early morning of 16 August. ALUMINAUT arrived that evening at 1900 and preparations for her first dive began immediately. However, the combined hazards of darkness and rising seas brought rigging of ALUMINAUT to a halt at 2300.

On the morning of 17 August, the salvage team resumed the difficult task of transferring the reel carrying the lift line from STACEY TIDE's deck and inserting it in brackets on ALUMINAUT's bow (figure 12). Rough seas with 5- to 7-foot swells and 20-knot winds hampered operations. The lift line reel, a backup reel, and ALUMINAUT's reel support bracket were badly damaged. The decision was made at noon to use the alternative plan for lowering the line (Appendix G).

Work to transfer the line and equipment from STACEY TIDE to MIZAR, assemble a backup clump, and rig MIZAR continued throughout the night and into the morning of 18 August. Because of worsening weather and anticipated effects of Hurricane Camille, an around-the-clock effort for rigging and diving preparations was mounted. The lift line clump consisted of a syntactic foam block (120-pound buoyancy), an AMF transponder, a Straza beacon, a Benthos flashing light, 500 feet of the lower end of the lift line made up into twenty five, 20-foot bights lightly sewn together, an aluminum toggle bar, and a special stern hook

a. Hoisting of lift line and reel into water.

b. Towing to ALUMINAUT. Note reel support brackets.



c. Fitting lift line reel in reel support brackets.

Figure 12. Positioning Lift Line and Reel on ALUMINAUT.

for the after lift fitting. Two 1,200-pound steel balls and a Stimson anchor were added to this assembly for holding position on the bottom. The lift line consisted of 6,450 feet of 4½-inch Columbian double-braided Plimoor nylon line to which was spliced an additional 750 feet of 4½-inch three-strand nylon line. The first two attempts to lower the clump failed when the clump was hauled to a vertical position because the light lashings on the bights parted, dumping the line on the deck. The third attempt was successful, and the clump was lowered to the bottom at 1856, 18 August.

MIZAR, using her computer and the transponder on the line, maneuvered above ALVIN and placed the clump within 100 yards of her. Two and one half hours of "flying" the clump were required to position it properly on the bottom. After paying out the remaining line, a large salvage pontoon and a watch buoy were attached to the end of the lift line and cast a-drift.

At 2005, ALUMINAUT submerged for her first dive, and, upon reaching the bottom, began the search for ALVIN. The search effort was hampered when ALUMINAUT's Straza sonar failed; however, MIZAR was able to direct ALUMINAUT to within visual range of ALVIN.

Upon arrival in the vicinity of ALVIN, ALUMINAUT experienced difficulty in observing ALVIN, as clouds of fine silt had been stirred up from the bottom. Dispersal of the silt clouds was slow because current was less than 1/2 knot. After waiting for the water to clear, ALUMINAUT carefully surveyed ALVIN and reported that, except for her damaged stern area, she was intact (figures 13 and 14), and her sensitive mechanical arm was still attached.

ALUMINAUT, using her manipulators, climbed ALVIN's sail "hand-over-hand." During this exercise, which was harder work for her manipulators than had ever been experienced, the manipulator thermal overload repeatedly tripped, delaying the operation. Shortly after midnight, ALUMINAUT announced that ALVIN's pressure sphere hatch was open and unobstructed.

ALUMINAUT next went in search of the clump. Upon locating the Benthos light on the lift line above the toggle, she descended vertically but was unable to locate the toggle. She ascended again and then followed the line, which was tending at an angle, to the bottom. She found the toggle and clump intact, pulled the toggle away, and carried it to ALVIN. While moving the toggle to ALVIN, ALUMINAUT lost her vertical motion motor. For the next several hours, she attempted to insert the toggle bar in the open hatch. The line leading from the end of the toggle became fouled under ALVIN's stern creating a moment that tended to upset the toggle balance. Other difficulties were encountered in handling the toggle because of the buoyancy material breaking free and changing the balance point. Hampered by lack of

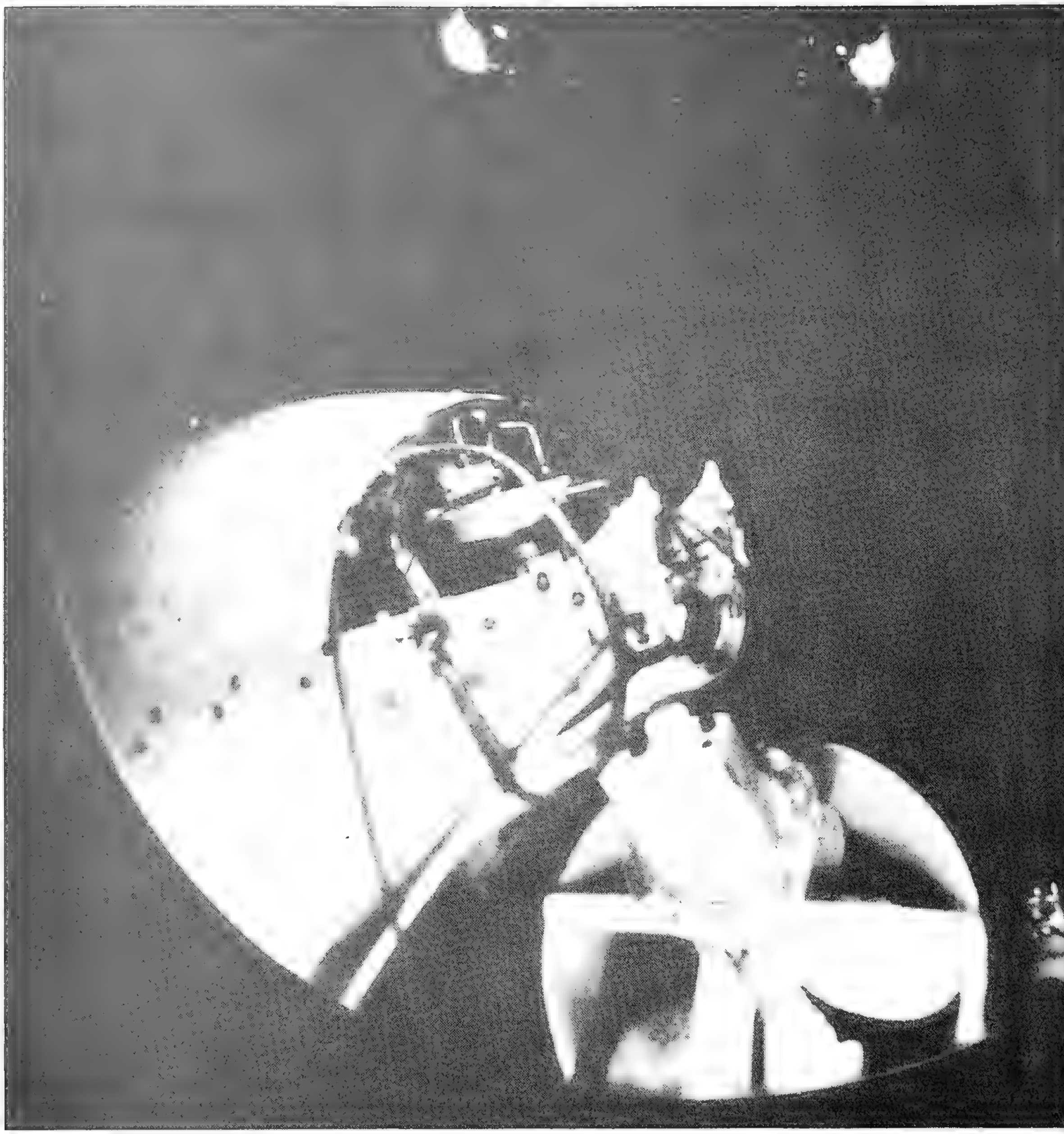


Figure 13. View of ALVIN's Stern Propeller Broken Away from Hull at Time of Accident. Hydraulic hoses kept this section attached to main portion of ALVIN.

maneuverability, a failed Straza sonar, and having expended all battery and life support system endurance, ALUMINAUT was ordered to leave everything in place and to return to the surface. She surfaced shortly after 0830, 19 August, for repairs and battery recharge.

High winds and heavy seas made battery recharge impossible. Waves of 5 to 7 feet were breaking over ALUMINAUT, and seawater was pouring into her hatches, opened for the recharging operation, causing grounds in the submersible. Closing the hatches during battery charging was not possible because it was necessary to ventilate the boat to remove hydrogen

Figure 14. ALVIN on Bottom.

gas generated during charging. Because side effects of Hurricane Camille were causing worsening weather in the operating area, the entire recovery force was ordered to return to Woods Hole in order to make repairs and to recharge ALUMINAUT's batteries in protected waters.

The ships left the site late on 19 August, leaving the lift line, with pontoon and watch buoy attached to the bitter end, in place. MIZAR and CRAWFORD arrived at Woods Hole early on 20 August, followed by STACEY TIDE and ALUMINAUT early the following day. The crews were confident that with a properly operating submersible they would be able to retrieve ALVIN on the next attempt.

REPAIRS AND SALVAGE PLAN MODIFICATION

Repairs to known malfunctions were accomplished quickly at Woods Hole on 21 August. However, during testing, a malfunction developed with a manipulator, which necessitated removing ALUMINAUT from the water. ALUMINAUT was sent to Boston on 22 August, where she was lifted out and repairs effected.

Because the original pendant holding the toggle was fouled on ALVIN, an alternate method of placing the primary lift device was prepared. A new toggle bar was built with a basic structure identical to the original one; however, aluminum angle was placed over the toggle handle pipe to form a square section, and the syntactic flotation material was placed on one side with a standoff. This arrangement allowed ALUMINAUT to grasp the toggle bar handle at any point. Since the only syntactic foam material available was of relatively high density (39 pounds per cubic foot), the maximum toggle bar dimension was increased to 16 inches, which made it difficult to handle through ALVIN's 20-inch hatch.

Attached to the toggle was a 25-foot nylon pendant with a snap hook on the tag end which was to be snapped onto the ring at the lower end of the lift line. It was planned to lift ALVIN from one point using the toggle bar as the only lift device. This was considered safe, because visual inspection indicated that the joint between ALVIN's fore- and afterbodies was in excellent condition. In addition, equitable division of the load between the toggle and stern hook would be difficult to achieve if a two-point lift were to be attempted.

ALUMINAUT's floodlight boom, removed to make room for the lift line, was replaced on her bow. A system was rigged to carry the toggle on the boom, leaving both of her manipulators free (figures 15 and 16). It was planned that ALUMINAUT would, as before, use her manipulators to grasp the steps and lifting padeyes on ALVIN's hull. When ALUMINAUT was in an almost vertical position, she would lower the bar into ALVIN's hatch and trip the holding pin so that the bar would swing perpendicular to the hatch and become securely lodged. She would then grasp the tag end of the toggle line and snap it into the lift line ring.

Figure 15. View of ALUMINAUT Submerged.

LIFT ATTEMPT NO. 2

On 27 August, the task force assembled once again at the recovery site. The buoy and pontoon supporting the lift line were still in place. ALUMINAUT, with four crew members and two observers, commenced diving at 1328 carrying the new toggle. She submerged about 2 miles from ALVIN's position, rather than being surface-towed closer, as it was felt that towing in the sea conditions that existed was likely to damage the new toggle mounting. MIZAR, being held near ALVIN's position, was unable to acquire ALUMINAUT with her tracking system for several hours. She was then relocated over ALUMINAUT in order to conn her to ALVIN. After a 5-hour submerged transit, ALUMINAUT reported that ALVIN was on her starboard bow.

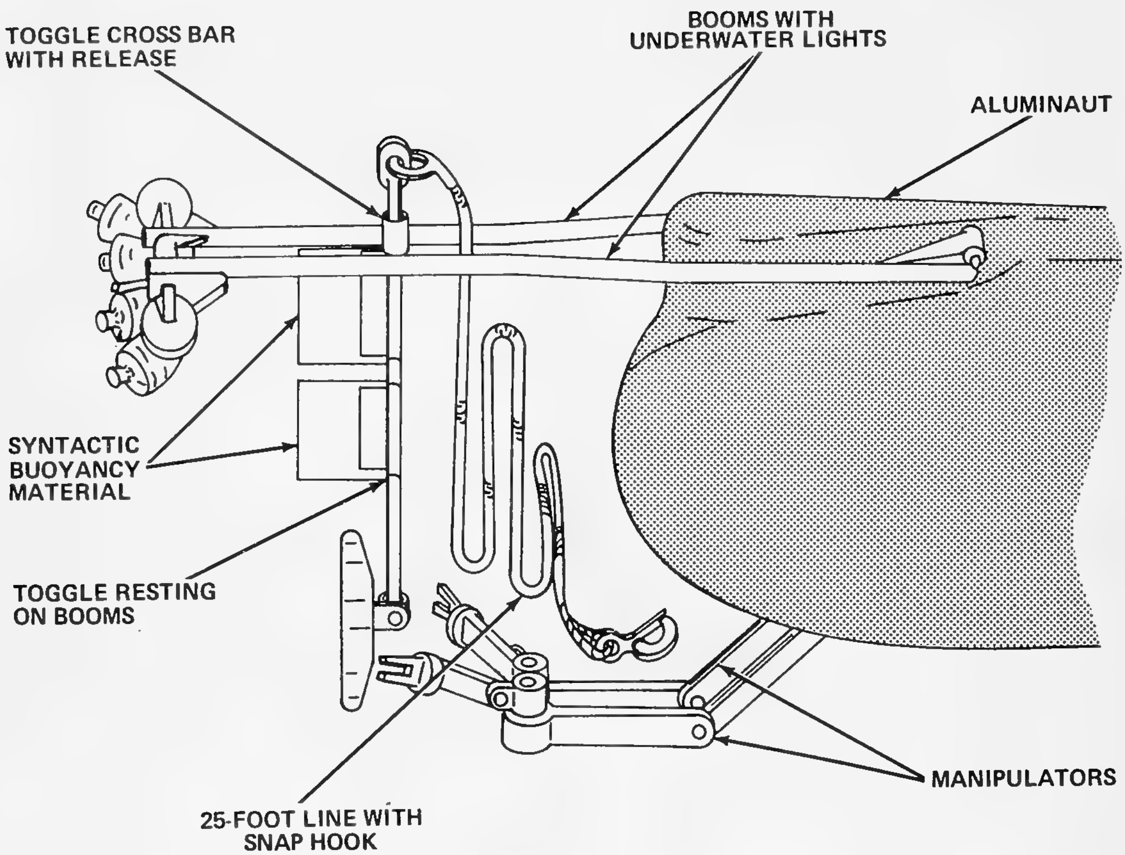


Figure 16. Toggle Attachment System on ALUMINAUT.

ALUMINAUT then began efforts to insert the toggle bar in ALVIN's hatch. She used one manipulator to hold onto ALVIN (figure 17) and the other to grasp the toggle bar handle. The toggle bar was difficult to maneuver because the syntactic material made it almost positively buoyant, and the joint between the toggle bar and wire handle was unexpectedly flexible. The toggle bar was nearly inserted in the sphere several times, only to float out again. The toggle was finally inserted after ALUMINAUT tore away part of ALVIN's fiberglass sail with her manipulators in order to properly position the toggle. ALUMINAUT then secured the tag end of the toggle line to the main lift line by attaching a snap hook to the ring which supported the original toggle and stern hook. No stern hook was to be used for this lift attempt. ALUMINAUT then moved above ALVIN, grabbed the lift line, and, by using her vertical lift propulsion system, tugged on the line. The line held indicating that the toggle was firmly emplaced. Next ALUMINAUT searched for 2½ hours to locate the steel balls and Stimson anchor to cut them free from the lift line. This search was unsuccessful, and ALUMINAUT surfaced at 0615, 28 August, after a dive of almost 17 hours.

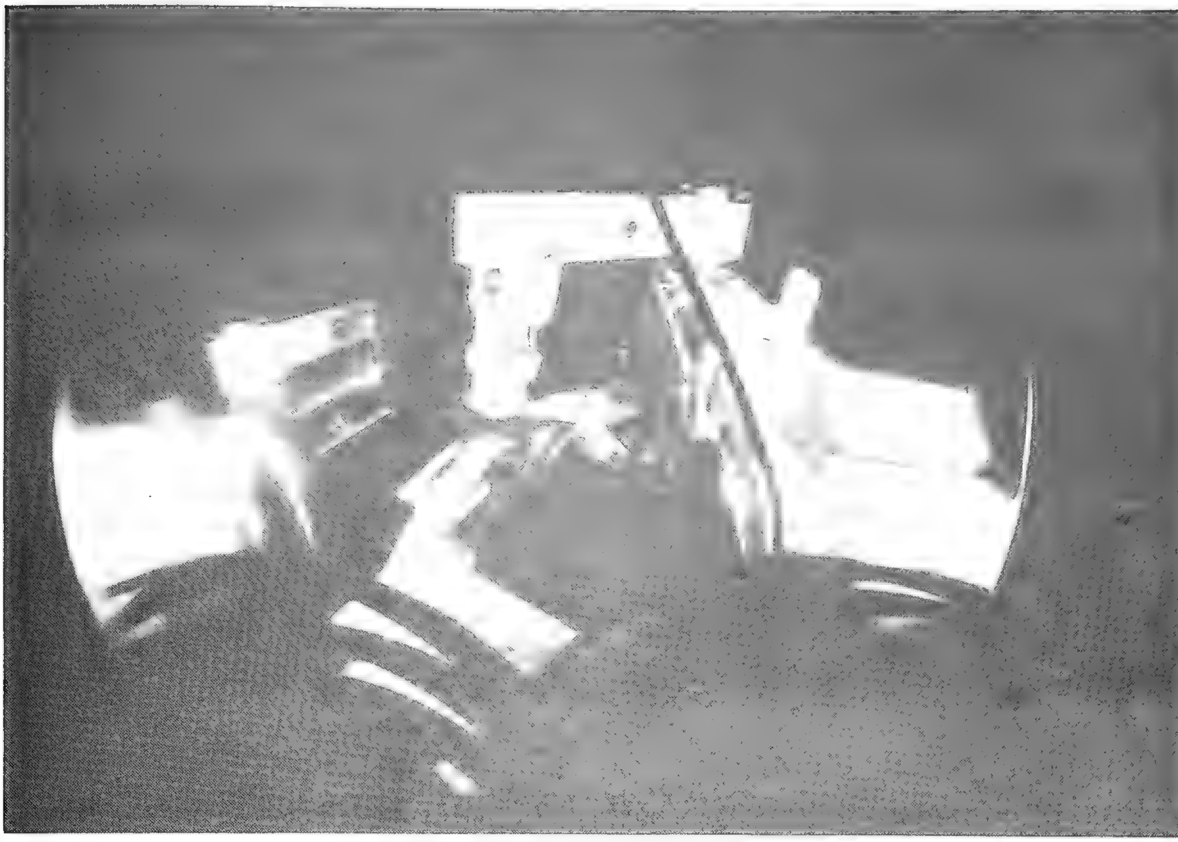


Figure 17. ALUMINAUT Inspecting ALVIN While Holding on to ALVIN's Sail with Her Manipulators.

During ALUMINAUT's dive, winds had died to less than 5 knots and seas had abated. Near ideal conditions existed when the lift of ALVIN began. The spherical buoy and pontoon supporting the bitter end of the lift line were brought alongside MIZAR, and the line was run through the center well to the traction and take-up winches. The buoy and pontoon were removed, and at 0830 MIZAR began hauling in on the lift line. At 1107, the readout for the load cell on the lift line steadied at 9,000 pounds indicating breakout had occurred. The low lift force, which was approximately equal to the in-water weight of ALVIN, indicated that the syntactic material was still fully effective. There was an approximate 200-pound reduction of lift force at breakout. The lack of appreciable breakout was attributed to the following: (1) the shape of ALVIN's lower hull was almost ideal for breakout; (2) the ocean floor was a shallow layer of unexpectedly soft silt over hard clay; and (3) the lift force was exerted at an angle to the vertical tending to roll ALVIN off the bottom.

Lifting proceeded smoothly and without incident. When the syntactic foam block, AMF transponder, Benthos light, steel balls and Stimson anchor came to the surface, they were removed from the lift line and stayed off for later recovery.

The lift was stopped when the lifting ring came up clear of the water and ALVIN was at 100 feet. Divers inspected ALVIN and attached her regular lifting bridle, which was suspended from an 85-foot-long, 1-inch wire pendant through MIZAR's center well.

Divers then secured loose and hanging equipment (such as propulsion motors and the manipulator) to ALVIN and commenced rigging for tow. Because dives at the 100-foot level were rapidly using up the divers' no-decompression dive time, ALVIN was yard-and-stayed alongside MIZAR in order to raise her closer to the surface and haul her to shallow depth. To accomplish this, a 6-inch nylon line was attached to the lifting bridle and the 4½-inch lift line was removed. The 4½-inch lift line was then rerigged over MIZAR's U-frame to the lifting bridle, and the 1-inch wire pendant was removed. (At no time were there less than two lines attached to ALVIN.) ALVIN then was hauled alongside MIZAR to a depth of about 30 feet.

An attempt was made to float ALVIN; however, leaks in the main ballast tanks prevented blowing them dry, and the toggle bar was jammed in the hatch, precluding insertion of the suction hose into the pressure sphere for dewatering. Had ALVIN been floated, she would have been supported in a cradle constructed of the inflatable pontoons, nylon net, and heavy timbers (figure 18). Because ALVIN could not be floated, she was lowered and rigged for submerged tow (figure 19). A protective nylon net (figure 20) was rigged around her to prevent accidental loss of any parts while under tow.

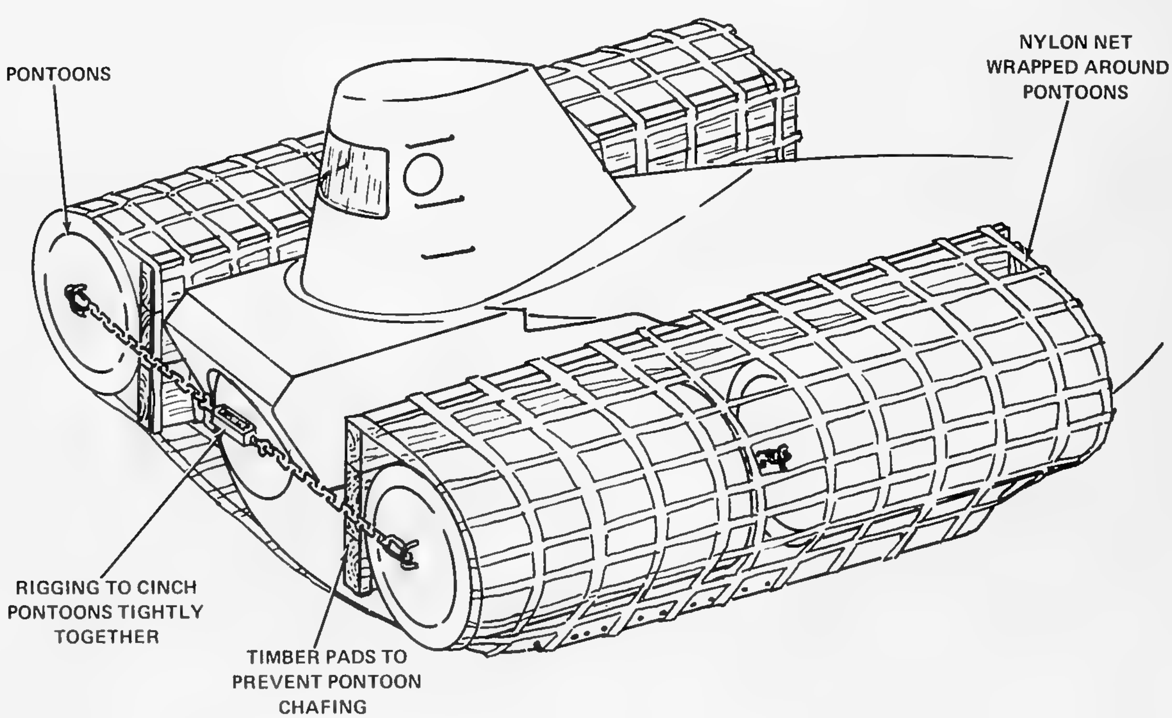


Figure 18. Sketch of ALVIN Cradle for Surface Tow.

Figure 19. Diver Checking ALVIN's Rigging for Tow.

Figure 20. Diver Lashing Nylon Web Net to ALVIN Underwater.

SUBMERGED TOW TO SHALLOW WATER

Two tow methods were available. One method was to tow ALVIN at a depth of 100 feet with the attachment point at MIZAR's center well (figure 21). This would require grounding ALVIN in at least 100 feet of water in a relatively exposed location in the open sea prior to final lift onto a barge. The other tow method was to suspend ALVIN at a depth of 40 feet from pontoons (figure 22). This would permit passage to the sheltered waters of Menemsha Bight, Massachusetts, for final lift onto a barge. This was selected as the more prudent course of action.

Three 8.4-ton inflatable salvage pontoons were firmly secured to ALVIN; one pontoon carried the load and the two additional pontoons, lashed together to minimize chafing, were attached for safety. A transponder, to be used for relocation in case the tow had to be bottomed, was also made fast to ALVIN's sail.

At 0220, 29 August, with the tow streamed 350 feet astern, MIZAR began the passage to Menemsha Bight at a speed of 2 knots. ALVIN was towed backward, suspended 35 feet beneath the surface. During the tow, one pontoon deflated and a second began to deflate.

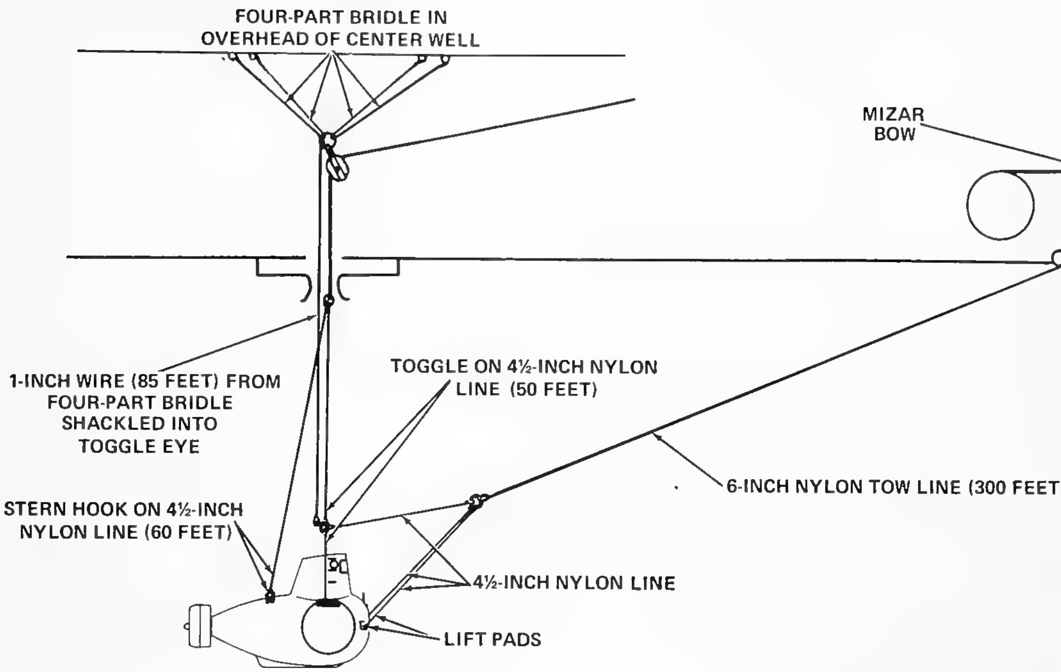


Figure 21. Rigging for Tow of ALVIN Through Center Well.

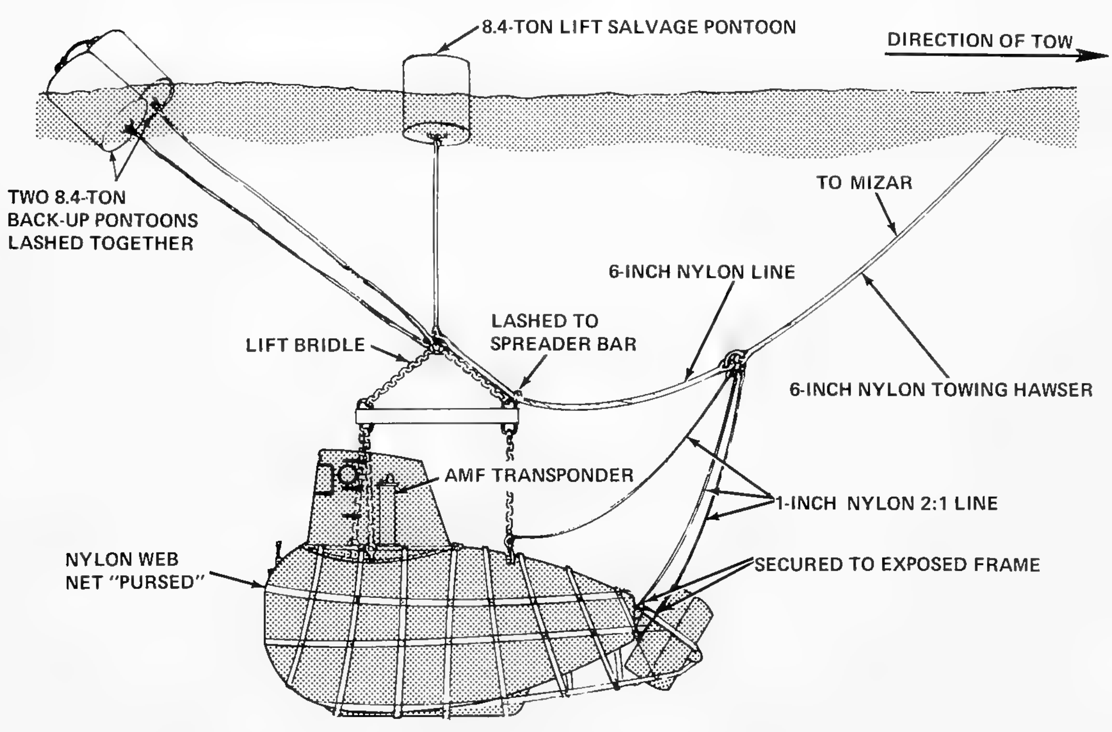


Figure 22. Rigging for Tow of ALVIN with Pontoons.

An additional pontoon was attached, and two more were made ready on deck in case they were required.

FINAL LIFT FROM WATER

MIZAR arrived at Menemsha Bight at 1630 on 31 August. Upon arrival, ALVIN was brought alongside and preparations were made for the final lift. All pontoons except one were removed and brought aboard MIZAR. The toggle bar was disassembled and removed from the pressure sphere.

On the morning of 1 September, a barge with a mobile crane aboard was brought alongside MIZAR. The crane's hook was attached to ALVIN's lifting bridle, the remaining lift pontoon was removed, and ALVIN was lifted to the surface. Her pressure sphere was then pumped out using portable gasoline-driven pumps.

Because inspection of ALVIN revealed that her stern lift fitting was slightly deformed indicating weakening, a wide nylon strap was rigged around the after-body. ALVIN was then lifted aboard the barge and placed in a cradle (figures 23 through 27).

When ALVIN had been secured on the barge, the barge was towed to Woods Hole where ALVIN was placed ashore and delivered to a representative of the Office of Naval Research.

CONCLUSIONS

As the final phase of the salvage efforts ended, the preservation and restoration of ALVIN began. All portable equipment was removed and placed in large tubs of fresh water. Equipment which could not be removed was thoroughly flushed with fresh water to reduce the effects of corrosion. Complete restoration is expected to require many months of effort.

The recovery of ALVIN is by far the deepest underwater recovery of an object of this size that has ever been successfully completed. The unparalleled success of this operation proves the Navy's capability of working in the deep ocean.

This operation, while a first, emphasized that no operation in which work in the deep ocean is undertaken is routine, and that each phase of the operation must be carefully and

Figure 23. ALVIN Being Prepared for Hoist Aboard Barge.

Figure 24. ALVIN Being Hoisted Aboard Barge.

Figure 25. ALVIN on Barge Alongside MIZAR.

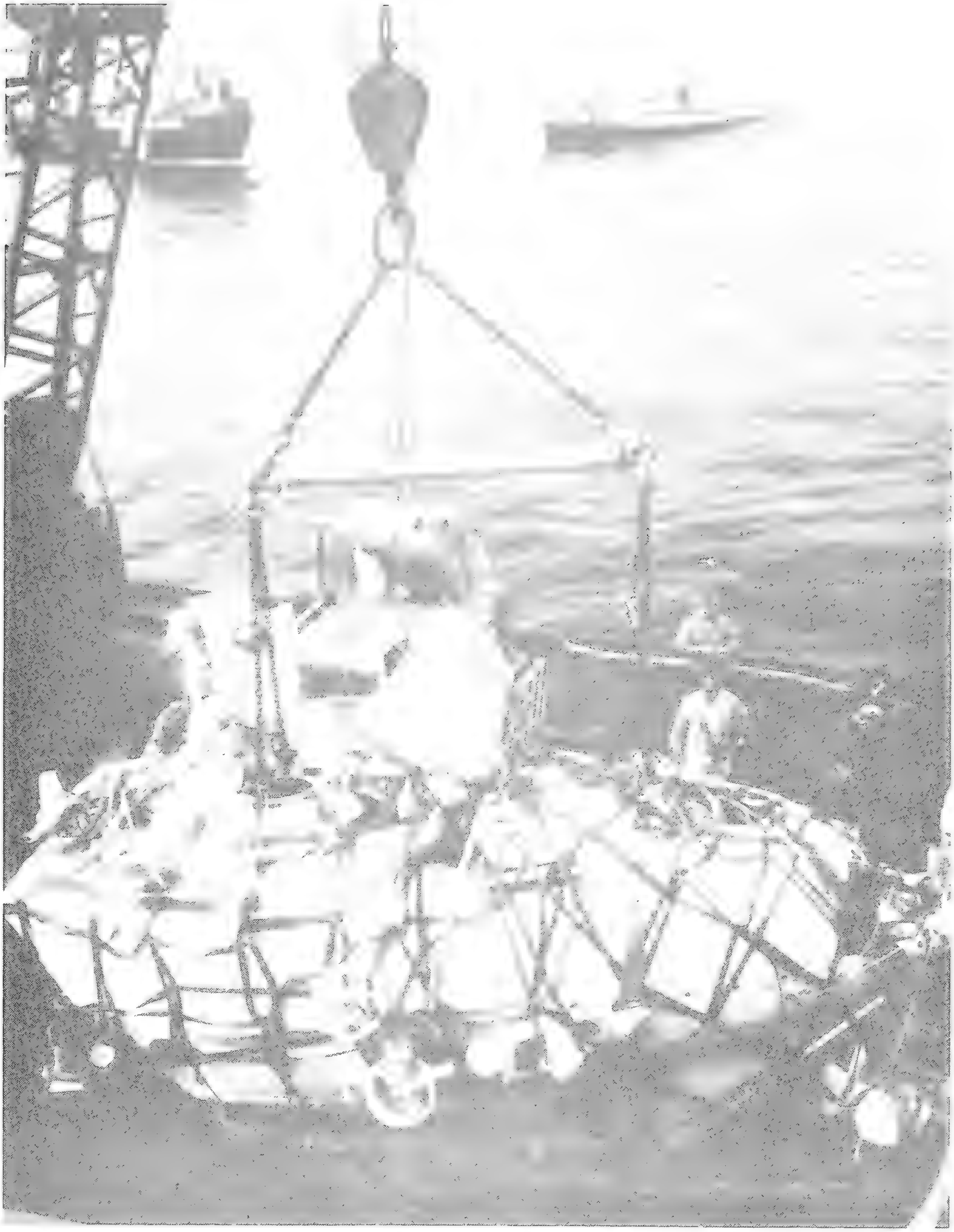


Figure 26. ALVIN, Wrapped in Protective Net, Resting on Barge Following Final Lift on 1 September 1969.

Figure 27. ALVIN on Barge – View of Aft Broken Propeller.

thoroughly planned. A secondary plan must be developed for each phase of the operation, and preparations for its implementation must be as complete as those for the primary plan.

Rehearsals of all significant phases of an operation should be conducted whenever possible. Such rehearsals can ensure that necessary modifications to the plans are made before the operation begins, and that personnel are thoroughly trained, thus making final performance so smooth as to seem anticlimactic.

Equipment and systems used for work in the ocean area must be simple and proven if they are to be effective. Use of unnecessarily complex or unproven equipment or techniques should be used only when no other course is open. Action at the air-water interface, such as the attempted reel loading on ALUMINAUT, should be avoided. Such action should take

place either on deck or completely submerged to reduce the effects of the interface. Practicality and excellence in seamanship are more essential to success in an ocean engineering evolution than accuracy of engineering effort.

In a complex and unique operation, a free flow of information among all concerned is necessary for effective action. When a number of activities are involved all must work together for the success of the project. Individual group interests cannot be served without a detrimental effect on project effectiveness.

The use of a manned submersible offers advantages over a remote-controlled unmanned vehicle. Having a human eye and brain on the scene permits otherwise unobtainable inputs to command, and permits easy and rapid modification of plans.

Because good seamanship was the rule, no safety program other than routine care was enforced. The recovery of ALVIN was accomplished without injury to personnel.

APPENDIX A

CHARTS

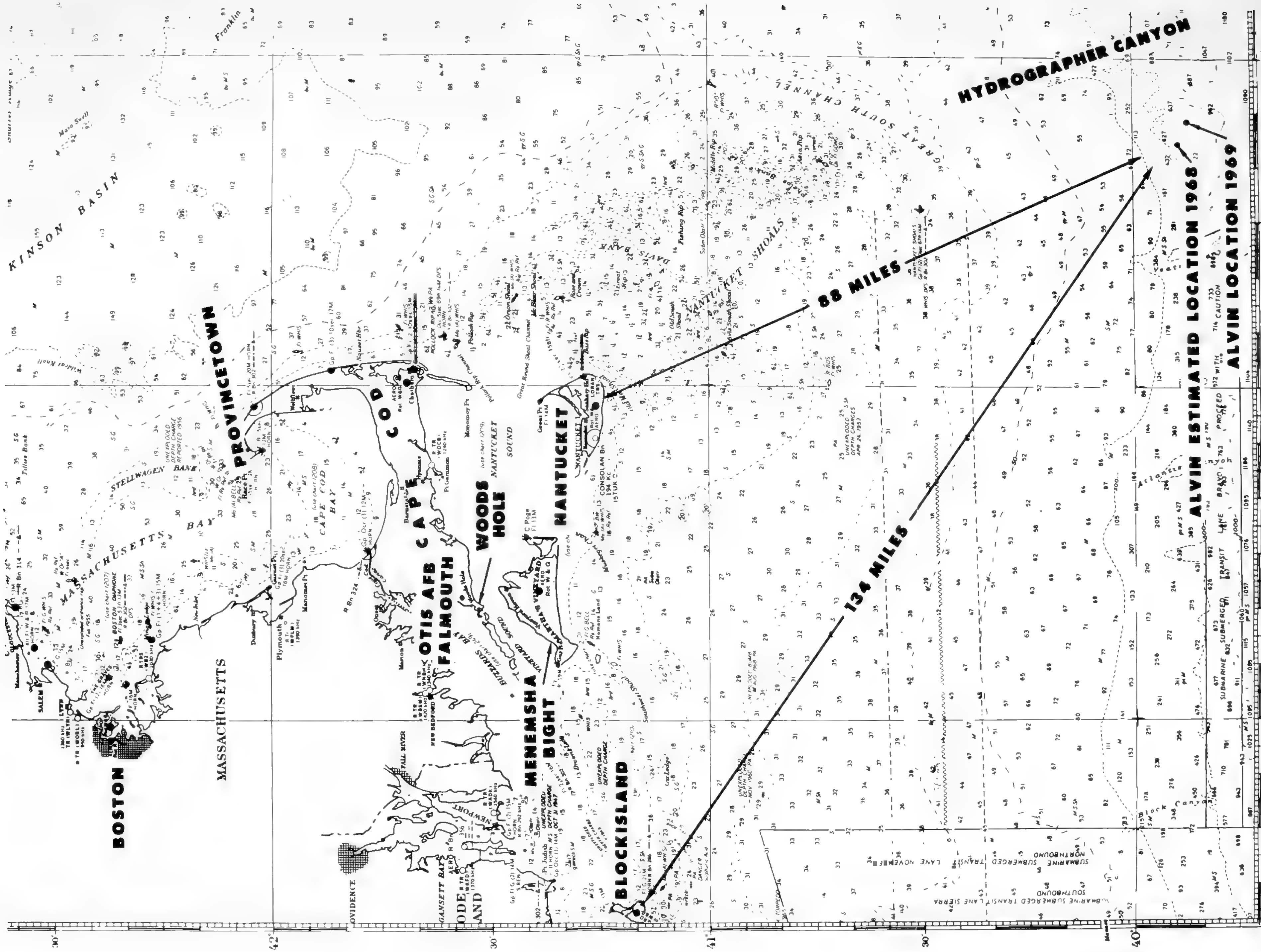


Figure A-1. Loss Area Chart

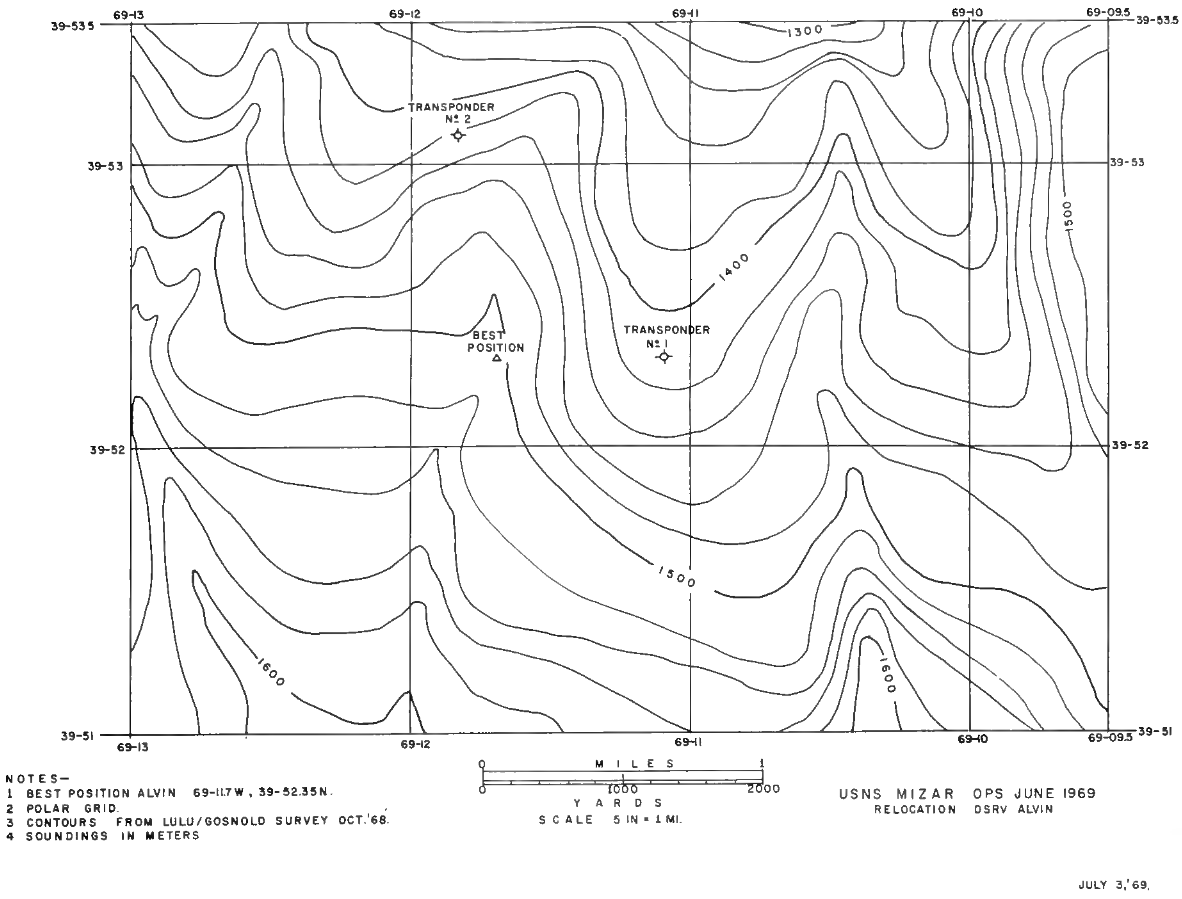


Figure A-2. Bathymetric Chart.

APPENDIX B

VESSEL CHARACTERISTICS

DRV ALVIN

ALVIN, a deep-diving oceanographic research submersible owned by the Office of Naval Research, was built by the Applied Sciences Division of Litton Industries (formerly the Electronics Division of General Mills, Inc.). The Naval Ship Systems Command assisted in the preparation of performance specifications for its design and construction.

ALVIN was placed in service on 5 June 1964 at the Woods Hole Oceanographic Institution. The vehicle is 23 feet long, has an 8-foot beam, displaces 16 tons, and has a draft of 7 feet in "surfaced" condition. She is designed to have a top speed of 3 knots, a cruising speed of 1.5 knots, and a submerged range of 10 to 15 miles. Her design operating depth is 6,000 feet with a safety factor of more than 2.6. The 7-foot-diameter pressure sphere is made of high-strength steel, 1.33 inches thick. There is room in the pressure sphere for a pilot and two observers, together with instrumentation and life-support equipment which will provide an endurance of 24 hours or more. Four viewing ports permit the pilot and observer to see ahead of and beneath the vehicle. The power for the vehicle comes from three banks of lead-acid batteries located in packages, which may be dropped in an emergency.

Additional facts include:

Total battery capacity: 60VDC, 27Kwh; 30VDC, 13.5Kwh

Maneuverability: Superior control of vertical and longitudinal, pitch and yaw motions.

Normal Instrumentation:

- Closed circuit TV
- Two 35-mm outside cameras, with strobe
- Scanning sonar
- Fathometer (without graphic recorder)
- Depth and temperature instrumentation
- Outside incandescent lights
- Gyro
- Magnetic compass
- Underwater telephone

Marine band radio
Current meter

Normal Optional Instruments:

Mechanical arm
Sample tray
Droppable pinger
Short coring and other geological tools
Water samplers
Plankton nets

DRV ALUMINAUT

The deep-diving submarine ALUMINAUT, owned by Reynolds Submarine Services Corporation, was launched at the Electric Boat Division of the General Dynamics Corporation in September, 1964. ALUMINAUT is an 81-ton submerged displacement submarine laboratory capable of carrying her operating crew of three or four men and three or four scientific passengers with scientific instrumentation payload of 6,000 pounds at an average speed of 2.5 knots for dive durations up to 30 hours.

ALUMINAUT has a design depth of 15,000 feet, with a safety factor of 1.5. The maximum depth achieved is 6,250 feet in 1967. The 8-foot-diameter pressure hull is made of 6.5-inch-thick aluminum alloy. Four silver zinc alkaline batteries provide power for all operating and scientific electrical loads. ALUMINAUT, which is 51 feet long, has four viewing ports. A hydraulically powered, two-arm manipulator is installed on the forward section of the keel. Maximum reach of each manipulator is 109 inches; at this length, lift capacity is 200 pounds each.

Additional facts include:

Normal dive rate: Descent - 100 fpm.
Ascent - 100 fpm (average).
Maximum deadweight lift capacity: 8,000 pounds plus.
Emergency ascent techniques: Release 4,500 pounds ballast bar.
Surface communications: 75-watt, six channel radiotelephone.
Submerged communications: Straza UQC.

USNS MIZAR

The USNS MIZAR (T-AGOR-11) is maintained and operated by the Navy's Military Sea Transportation Service, Atlantic Command (MSTSLANT). She was built in 1957 by Avon-

dale Marine Ways, Inc., New Orleans, Louisiana. After having been originally designed as an Arctic/Antarctic ice-strengthened supply ship, MIZAR was converted in 1964 to function as a seaborne scientific research platform for oceanologic research conducted by the Naval Research Laboratory. MIZAR is of welded steel construction and is 266 feet long. Displacement with fuel load is 4,500 tons. Average speed is 13 knots.

MIZAR first gained fame by locating the hull of the nuclear submarine (SS(N)) USS THRESHER, and again by locating the hull of the SS(N) USS SCORPION. A key component in her success is her integrated system of instruments, which enables the ship to place an acoustic marker on the ocean floor and then make a complete exploration of the surrounding area. The system permits making photographs of the selected area simultaneously with other measurements, such as magnetic strength and acoustic echoes, so that results can be correlated with the photographic record.

During 1965, a center well, 23 feet long by 10 feet wide, was added to the ship for the purpose of lowering equipment and material into the sea without having to hoist them over the side.

Late in 1965, MIZAR again gained fame for her participation in the search for a nuclear bomb lost off the coast of Spain. She was able to direct recovery of the bomb by providing navigational guidance for ALVIN, and pinpointing the bomb's location once it had been sighted.

APPENDIX C

EQUIPMENT FOR ALVIN SALVAGE OPERATIONS

SALVAGE LINES

Selection of a lift line was particularly significant because a long line lift from such a great depth had never been attempted, and the behavior of such a long lift line was not easily and accurately predictable. No experience was available upon which to base selection of the line. The following factors were considered in selecting a line:

- Adequate strength to make the lift with a large factor of safety.
- Suitable elasticity to respond to shock loading without undue ill-effects.
- Maximum flexibility for ease of handling.
- Minimum in-water weight.

Using these parameters and surveying available lines, three choices were presented:

- A specially made piece of Columbian 4 1/2-inch double-braided nylon Plimoor nominally 7,000 feet in length.
- Several pieces of Samson 2-in-1 4 1/2-inch double-braided nylon which could be joined by splicing.
- Four 1,600-foot pieces of 8-inch polypropylene which could be joined by splicing.

4½-inch (circumference) Columbian Double-braided Nylon Plimoor Line

Because the Columbian line fulfilled all the requirements and had the advantage of being a single piece of line thus losing none of its strength in splices, it was chosen as the primary lift line. This single piece of line, with a breaking strength of 53,000 pounds, was initially wound on a reel which was to be attached to ALUMINAUT during its descent to the bottom. After the reel was damaged, the line was removed from the reel and wound on a lift system on MIZAR (the lift system consisted of a double drum traction winch and a Naval Oceanographic Office take-up winch).

4½-inch (circumference) Samson Braided Nylon Line

This line, 7,000 feet long with six factory splices, was used as a backup lift line. It had a breaking strength of 53,000 pounds.

8-inch (circumference) Polypropylene Braided Line

Four lengths, 1,600 feet each, were long-spliced together. This line, having a breaking strength of 160,000 pounds, was available if required.

TOGGLE BAR AND STERN HOOK

A toggle bar was fabricated in 1968; however, several possible weaknesses existed: (1) the eye was underdesigned so that it would pull out if the pull were exerted at an angle of 5° or greater; (2) high local stresses might occur in the hull to cause deformation of the hull and yielding in the upper flange of the toggle bar; and, (3) two existing serious design faults indicated that the toggle bar was generally of inadequate design and that additional faults were likely to surface should the bar be used.

During outfitting for 1969 salvage operations, the toggle was redesigned and made of 80-pound steel plate contoured to fit the sphere of ALVIN. However, this toggle was unacceptably heavy and required excessive syntactic foam to be added to reduce its weight to that which ALUMINAUT could handle in the water. Nine holes were cut into the bar to lighten it; however, the weight problem, though alleviated, was not solved.

On 11 August 1969, a toggle was made of 2-inch aluminum plate, contoured to fit ALVIN's sphere in order to broaden the area of contact and reduce local stresses. This device was tested in both air and water and was found satisfactory to handle.

A 9-foot-long toggle bar handle was constructed using a 1-inch wire rope enclosed in an aluminum pipe for rigidity. A poured socket was formed on each end. The toggle was held parallel to the handle by a quick release pin, the release for which was led up the handle. Elastic cord was provided to snap the toggle into position perpendicular to the handle. To assist in this function syntactic foam, with a density of 33 pounds per cubic foot, was asymmetrically banded to the toggle to give a weight and buoyancy moment. Additional syntactic material was banded to the toggle handle to reduce the in-water weight of the assembly. Three I-section grips were attached along the handle to allow ALUMINAUT to handle the toggle assembly. During the first lift attempt some of the syntactic foam worked loose, causing the in-water center of gravity to change and making its suitability for the second lift attempt questionable.

A U-shaped steel hook was to be used for attaching the lift line to ALVIN's stern lift fitting. The stern hook, depicted in figure 4, was specially designed with hinged dogs which would lock automatically as the hook was positioned over ALVIN's frame bar.

The toggle and stern hook were attached to two lengths of nylon line, sized 50 feet and 60 feet respectively, in order to equalize the strain during the lift. This two-part lifting bridle was in turn attached to a ring in the lower end of the main lift line.

Using the lessons learned during the first lift attempt, a new aluminum toggle was fabricated and a different method of insertion and lift line connection was planned for Lift Attempt No. 2. The basic structure of the new toggle was identical to the first except that: (1) the aluminum pipe was covered with aluminum angle to form a square section so that ALUMINAUT could grasp the toggle bar handle at any point; and (2) syntactic flotation material was placed on one side of the handle. Only high density material (39 lb/cu. ft.) was available. This increased the maximum toggle bar dimension to 16 inches requiring skillfull handling through ALVIN's 20-inch hatch.

A 25-foot nylon line with a snap hook on the end was attached to the toggle. The snap hook was designed to be snapped onto the ring on the lower end of the lift line. It was planned that the toggle bar would be the only lift device, and that the stern hook, designed for use in the first lift attempt, would not be used. The toggle would be carried on a light boom fastened to ALUMINAUT's bow, leaving both of ALUMINAUT's manipulators free to assist in holding ALUMINAUT in position and securing the toggle in ALVIN's sphere.

DIVERS AND DIVING EQUIPMENT

Three First Class Divers were obtained on loan from Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island. The use of SCUBA equipment was not permitted because of the nature of the dives and the desirability of having communications between the diver and his tenders during tedious work. As no standard Navy diving equipment fulfilled the requirements for both mobility and communications, permission was granted by the Supervisor of Diving, U.S. Navy, to use commercial equipment to fulfill the requirements. The Kirby-Morgan KMB-8 Band Mask, Gates 3/8-inch diver's air hose and commercial divers telephones were chosen. This equipment had been extensively tested at the Navy Experimental Diving Unit prior to its operational use. A standard portable 125-CFM Ingersoll-Rand diesel-driven diver's compressor was used as the air supply.

RECOVERY WINCH

This winch was built for WHOI to lower ALVIN for an unmanned dive to 7,500 feet in 1965. It was a double traction winch, each drum powered separately by a synchronous 10-hp motor through a reduction gear and chain drive. This winch was bolted to foundations welded to the deck of MIZAR.

Because chain failure was experienced during system testing at Boston Naval Shipyard and again during lowering of the clump, some question arose as to the reliability of the winch. However, after a chain cover was fabricated and placed over the chain to keep foreign material away from the chain and sprockets no additional failure was experienced.

ANCHOR

Two, 1,200-pound headache balls and a Stimson anchor served to anchor the lift line (clump) while the recovery gear was being positioned. This anchor was left on the bottom between Lift Attempts No. 1 and No. 2 to hold the line and toggle in the vicinity of ALVIN. The anchor was recovered during the lift.

SALVAGE PONTOONS

Standard B.F. Goodrich inflatable rubber pontoons rated at 8.4-ton buoyancy lift were used. After MIZAR had lowered the lift line and toggle into the water, a pontoon was used to suspend the bitter end of the line thus permitting the line to be cast off from the ship. Casting the line free from the ship eliminated the effects on the line of MIZAR's motions and maneuvering. This pontoon supported the lift line while the task force was in Woods Hole for repairs, and was also used to support ALVIN during the tow to shallow water.

Two additional pontoons were attached for safety. These pontoons became deflated during tow, presumably from chafing, and were replaced by an additional pontoon. Two more pontoons were made ready on deck in case they were required.

SALVAGE NET

A 30-foot by 30-foot net of nylon webbing was used. The net was buoyed by lengths of polypropylene pipe, and contained a nylon line to permit the net to be gathered. When ALVIN was near the surface, this net was wrapped around her and gathered to help secure her for the tow to shallow water and prevent loss of any equipment.

EQUIPMENT LIST

Description	Weight (pounds)	Dimensions (inches)
Long-line winch - power required 400V - 3 phase - 28A 120V 1 phase 2A plus 1 spare motor and chain	8,000	40 x 132 x 48
Foundation adapter	500	
Lift attachment slings	100	24 x 24 x 72
Toggles	460	20 x 20 x 144

Description	Weight (pounds)	Dimensions (inches)
Tensiometer for longline	50	18 x 18 x 36
Block for 8-inch polypropylene and 4-inch nylon plus fairleads (3)	50 ea.	24 x 24 x 36 ea.
Salvage pontoons, 300 feet of air hose, and hose fittings to inflate (4)	600 ea.	60 x 60 x 24 ea.
Salvage net plus spreader (2)	100 ea.	24 x 24 x 100 ea.
Charts and data on area	10	12 x 12 x 24
Spare P.G.R.'s 19-inch (2)	30 ea.	20 x 18 x 8 ea.
Straza UQC	80	17 x 20 x 28
Straza 500	250	53 x 53 x 40
Straza transponder (3)	40 ea.	45 x 12 x 12 ea.
EDO transponder (2)	40 ea.	58 x 11 x 10 ea.
MB blow fittings	10	6 x 6 x 12
Nylon tie down strap (10)	5	12 x 12 x 36
Spare 4 1/2-inch nylon (7,000 feet) and reel	4,500	50 x 50 x 50
Benthos lights in basket (2)	35 ea.	36 x 36 x 20 ea.
Radio (walkie talkie radio and Pearce Simpson)	15	5 x 8 x 12
8-inch braided polypropylene (6,400 feet)	10,000	96 x 96 x 96
Headache balls (2)	1,200	36 x 36 x 36 ea.

Description	Weight (pounds)	Dimensions (inches)
Storage shack	1,500	72 x 96 x 90
Hose and fitting to dewater sphere	10	8 x 8 x 20
Scuba gear (4 sets)	100 ea.	24 x 24 x 24
Whaler with radio plus cradle	2,000	80 x 80 x 195
Portable UQC-NEL	80	20 x 24 x 12
Transducer for UQC	80	20 x 24 x 24
LULU tracking gear (Marker-Receiver)	12	19 x 2 x 14
Glass spheres (6) + syntactic foam	100	36 x 36 x 36
Rubber boat plus outboard	500	24 x 24 x 60
Air charging van 440V 3-phase 20A		80 x 80 x 120
Omega receiver	50	12 x 17 x 36
Various shackles, wire pendants, stoppers, pelican hooks, etc.	1,000	
Six nylon (6-inch) stoppers endless (2 10-foot, 2 15-foot, and 2 20-foot)		
One backup salvage winch Clyde, line pull 16,000-pound with spares	3,000	
2,000 feet (one box) 8-inch nylon braided line (from ESSM Pool, Bayonne)	3,500	48 x 48 x 120
One spare dynamometer (0 to 40,000 pound)	75	
Two 15-foot 6-inch nylon straps		
Two 25-foot 6-inch nylon straps		

Description	Weight (pounds)	Dimensions (inches)
Two 50-foot 6-inch nylon straps		
Two 75-foot 6-inch nylon straps		
One reel 100-foot 6-inch 2-in-1 nylon	100	
One reel 200-foot 6-inch 2-in-1 nylon	200	
One reel 300-foot 6-inch 2-in-1 nylon	300	
One reel 400-foot 6-inch 2-in-1 nylon	400	
One reel 1,200-foot 3-inch 2-in-1 nylon (breaking strength 28,000 pounds)	300	
One reel 500-foot 6-inch 2-in-1 nylon	500	
One 16-inch wooden snatch block (line)	50	
One 14-inch steel snatch block (line)	50	
One 14-inch single block (wire)	50	
One 14-inch steel double block (wire)	50	
Two chain stoppers		
Ingersoll-Rand diesel-driven portable 125 CFM diver's air compressor		
Line footage counter		
NAVOCEANO constant tension take-up winch		
Two Kirby-Morgan KMB-8 diver's band masks		

Description	Weight (pounds)	Dimensions (inches)
Pro-Fiber Phone and Ocean Systems, Inc. diver's communications sets		
Two 200-foot lengths Gates 3/8-inch diver's air hose		

COST OF EQUIPMENT AND SERVICES

Nylon line (4 1/2-inch) 6,400 feet, with 2 reels	$13,304.00
Nylon line (6-inch) 400 feet	800.00
Nylon line (6-inch) 500 feet	1,000.00
Splicing of 4 1/2-inch 2-in-1 nylon line	100.00
Nylon lift bridle	150.00
Accelerometer filter reproduction equipment	574.00
Various shackles	420.00
Two 15-foot (6-inch) nylon straps	300.00
Two 25-foot (6-inch) nylon straps	320.00
Two 50-foot (6-inch) nylon straps	350.00
Two 75-foot (6-inch) nylon straps	375.00
Boston NAVSHIPYD services and materials	38,000.00
ALUMINAUT charter and services	335,173.00
Ocean Systems, Inc.	
Services - Direct Labor, Overhead and Profit	34,935.00
Purchases	13,878.00

APPENDIX D

CALCULATIONS

Section 1

Calculations By Naval Ship Engineering Center

INTRODUCTION

At the request of NAVSHIPS OOC, NAVSEC conducted studies to evaluate various aspects of the ALVIN Salvage Plan. The analysis and results contained herein were originally submitted to NAVSHIPS OOC as Enclosures (1) and (2) of NAVSEC 6162 Memo Serial 229, 15 August, 1969. Acknowledgement is made to H. W. Stoll of Deck Systems Branch, NAVSEC, for his assistance in the preparation and compilation of these studies for inclusion in this ALVIN salvage report.

DISCUSSION

Plans for the salvage of the submersible ALVIN called for the use of a 4½-inch-circumference Plimoor nylon rope to lift ALVIN from nearly 5,000 feet of water. The lift was to be made using USNS MIZAR. Concern was expressed over the possibility that dynamic resonance may be generated during the lift by ship motion exciting the spring-mass system formed by ALVIN and the nylon rope.

NAVSEC analyzed this spring-mass system with the intent of establishing the extent of the resonant problem and the hope of suggesting possible preventive action. Accordingly, the spring-mass system was analyzed for the following cases:

Case I

In a meeting of interested parties held on Wednesday, 30 July 1969, it was agreed that the lift line would be deployed through the center well of MIZAR in order to prevent roll and pitch motion from exciting the spring-mass system. ALVIN's mass including apparent mass effects was assumed to be 1,300 lb-sec^2/ft^4 and her static weight in water was assumed

to be 10,000 pounds. The spring-mass system was assumed to be excited by a sinusoidal ship heave described by the equation:

$$\textit{Ship heave motion} = Y \sin \frac{2\pi}{T} t$$

Where Y is the maximum heave amplitude of the ship in feet and T is the period of the motion in seconds. Four amplitude-period combinations were assumed as follows:

AMPLITUDE *(Y)*	PERIOD *(T)*
1 foot	5 seconds
2 feet	10 seconds
3 feet	15 seconds
4 feet	20 seconds

The rope used was specified as 4½-inch circumference Plimoor nylon. Figure D-1 shows a plot of maximum line tension versus line length for the conditions described above.

Case II

Maximum line tensions were computed using a MIZAR heave period predicted by Kreitner's approximation (DTMB Report 1235, Sept. 1958) and heave amplitudes supplied by NAVSEC Code 6136 for MIZAR. All other parameters were assumed to be the same as given in Case I. Figure D-2 is a plot of maximum line tension versus line length for the conditions of Case II.

Case III

The spring-mass system was analyzed using 4½-inch circumference Plimoor nylon rope, 8-inch circumference Plimoor nylon rope, 4½-inch circumference Samson 2-in-1 nylon rope, and 8-inch Samson 2-in-1 nylon rope. For these cases, the rope was assumed to be deployed from the U-frame located at Station 40 on MIZAR. Consequently, roll and pitch motion were included as additional exciting motions. Amplitudes and periods used were provided by NAVSEC Code 6136 as described in Case II. Static weight of ALVIN in water was assumed to be 9,000 pounds and 12,000 pounds (i.e., 0% and 33% loss in buoyancy due to syntactic foam saturation). Figures D-3 and D-4 are plots of maximum line tension versus line length for the various conditions described above.

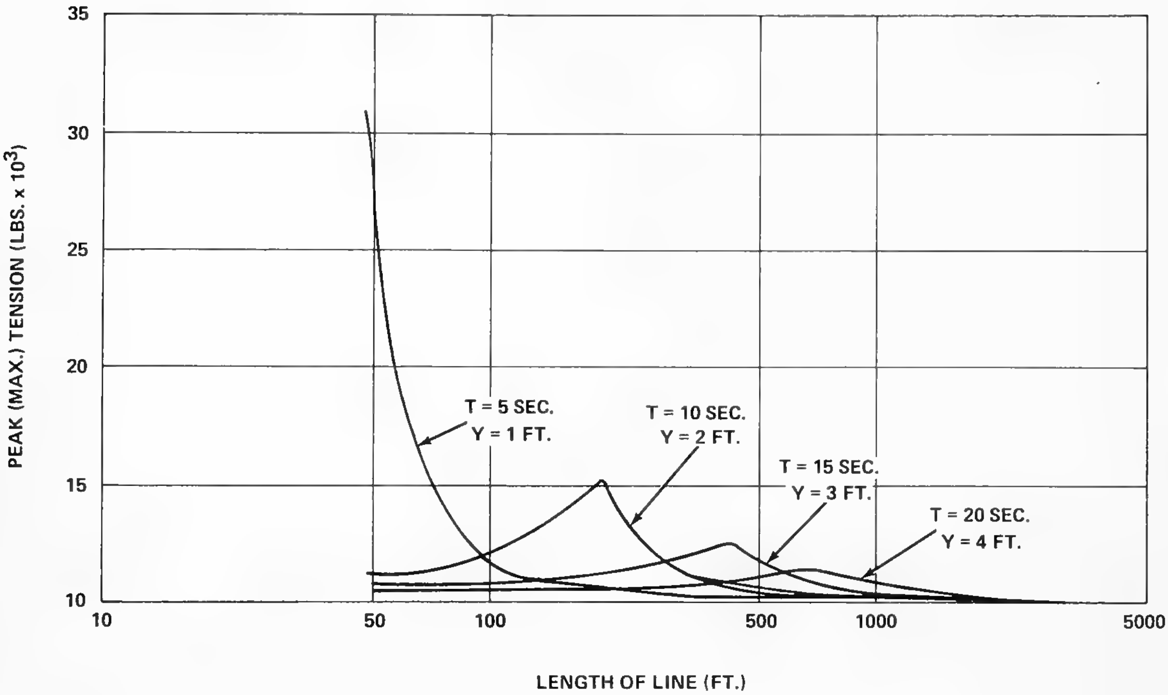


Figure D-1. Peak Line Tension Versus Line Length for Case I.

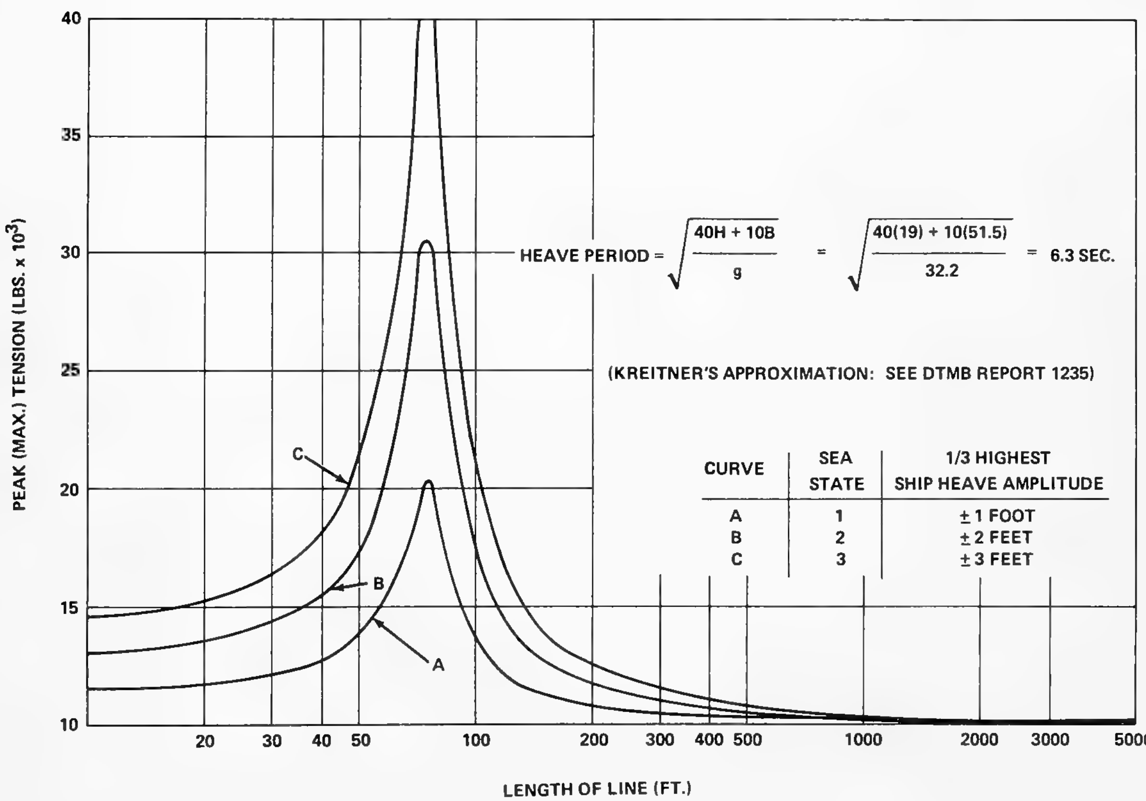


Figure D-2. Peak Line Tension Versus Line Length for Case II.

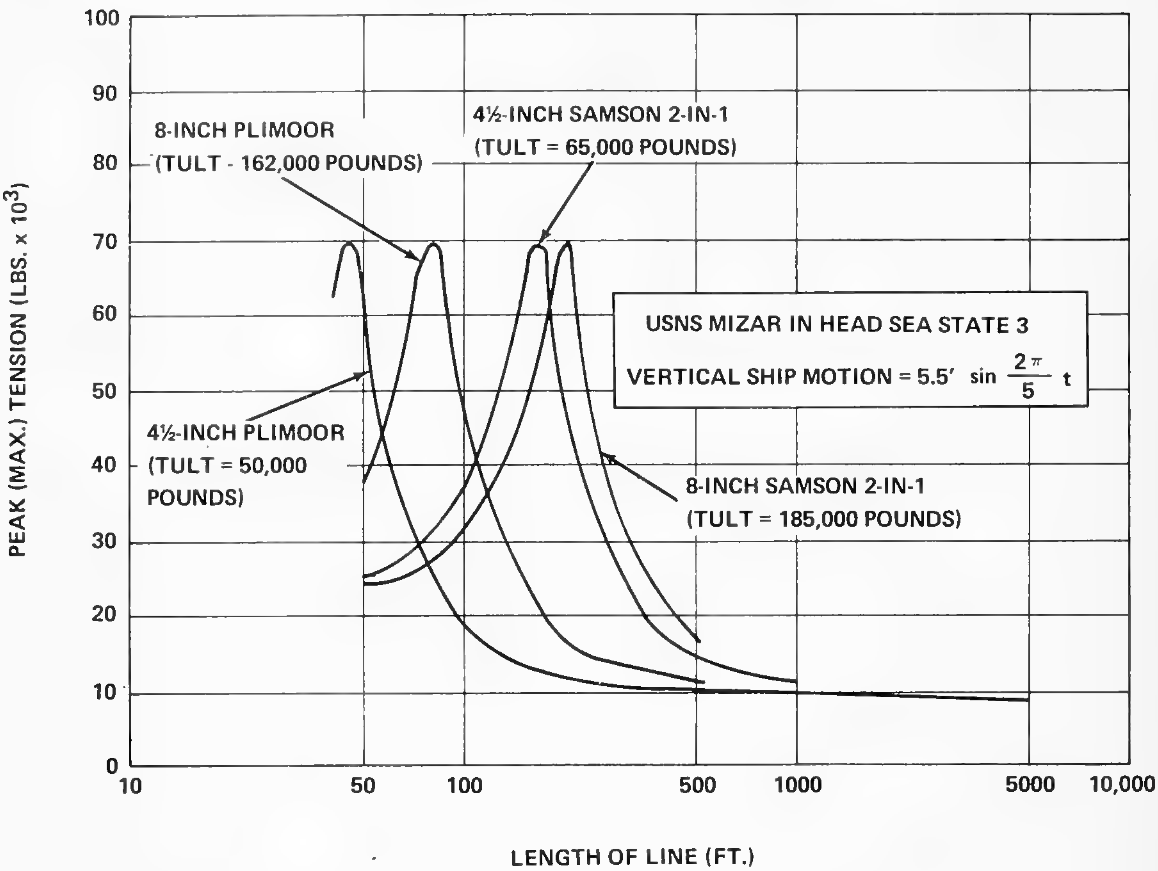


Figure D-3. Peak Line Tension Versus Line Length for Case III – ALVIN Weight 9,000 Pounds.

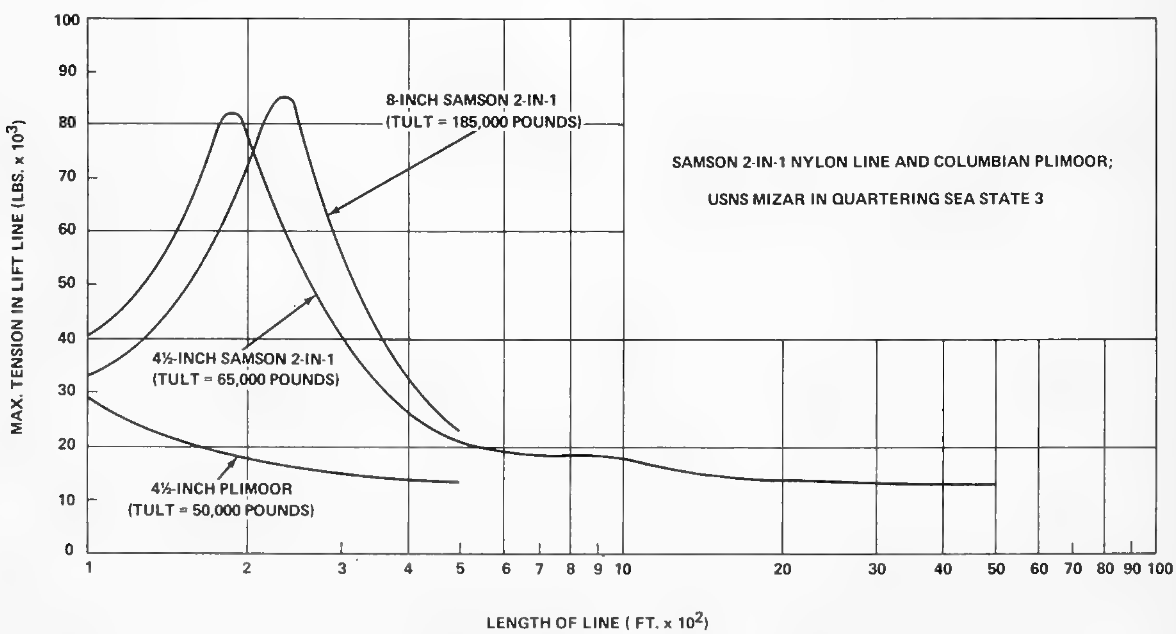


Figure D-4. Peak Line Tension Versus Line Length for Case III – ALVIN Weight 12,000 Pounds.

DYNAMIC ANALYSIS

Assumptions

Because of limited time, the lumped formulation of the system as shown in figure D-5 is assumed sufficiently accurate for determining resonant points and approximate maximum loads. To further simplify the analysis, the following assumptions are made:

1. Assume the system is linear. This implies the following:
   a. The principle of superposition holds.
   b. The fact that the spring rate is constantly changing as the rope is hauled in is ignored; i.e., the system is treated as a discrete, steady state spring-mass system at each incremental change in rope length.
   c. The non-linear spring rate of the nylon rope is linearized at the static load.
2. Assume transients due to initial conditions and changing parameters to be negligible compared to steady state values.
3. Assume that the line hangs vertical; i.e., no horizontal current or ship motion.

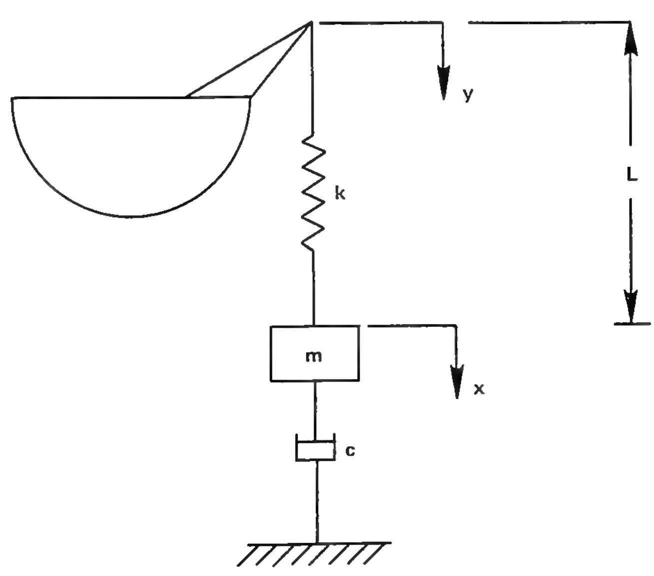


Figure D-5. Analytical Model for Simplified Spring-Mass System.

Analysis

Definitions

k - linearized nylon rope spring rate (lb/ft)

m - effective mass of ALVIN (includes added mass effect) (lb - sec^2/ft^4)

c - linearized damping due to water drag (lb - sec/ft)

y - displacement of MIZAR (feet)

x - displacement of ALVIN (feet)

From Figure D-5,

$$m\ddot{x} + c\dot{x} + k(x - y) = 0 \tag{1}$$

Let $z = x - y$, which is the relative motion between MIZAR and ALVIN. Substituting into eq. (1) gives,

$$m\ddot{z} + c\dot{z} + kz = m\ddot{y} + c\dot{y} \tag{2}$$

Assuming sinusoidal motion,

$$y = Y \sin \omega\, t$$

where Y = amplitude of steady oscillation

$$\omega = \frac{2\pi}{T}$$

T = period of ship motion

A solution to eq. (2) can then be assumed as,

$$z = Z \sin (\omega t - \phi)$$

and eq. (2) solves to give

$$\left|\frac{Z}{Y}\right| = \sqrt{\frac{(-m\omega^2)^2 + (c\omega)^2}{(k - m\omega^2)^2 + (c\omega)^2}} \tag{3}$$

Letting

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\zeta = \frac{c}{2m\,\omega_n}$$

eq. (3) becomes,

$$\left|\frac{Z}{Y}\right| = \sqrt{\frac{\left(\frac{\omega}{\omega_n}\right)^2 \left[\left(\frac{\omega}{\omega_n}\right)^2 + (2\,\zeta)^2\right]}{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + (2\,\zeta)^2 \left(\frac{\omega}{\omega_n}\right)^2}} \tag{4}$$

Maximum line tension can then be expressed as,

$$T_{max} = W + \sum_{n=1}^{3} k \left|\frac{Z}{Y}\right|_n Y_n \tag{5}$$

where W = weight of ALVIN in water

Y_1 = ship heave amplitude

Y_2 = vertical motion at point of lift line suspension due to ship roll

Y_3 = vertical motion at point of lift line suspension due to ship pitch

$\left|\frac{Z}{Y}\right|_n$ = amplitude ratio evaluated at ship heave, roll, and pitch natural frequencies, respectively

The natural frequencies are defined as follows:

$$\omega_1 = \omega_H = \frac{2\pi}{T_H}\ ; \quad T_H = \text{heave period}$$

$$\omega_2 = \omega_R = \frac{2\pi}{T_R}\ ; \quad T_R = \text{roll period}$$

$$\omega_3 = \omega_P = \frac{2\pi}{T_P}; \qquad T_P = \text{pitch period}$$

Determination of ALVIN Mass

ALVIN weight in air prior to sinking = 33,051 pounds with MBT full. From discussions with Ocean Systems, Incorporated,

$$\textit{Effective ALVIN Mass} = \frac{\textit{wt. in water}}{g} + \frac{\textit{wt. of entrained water}}{g} + \frac{24{,}300}{g} \tag{6}$$

where the $\frac{24{,}300}{g}$ term is the added mass effect based on ALVIN surface characteristics.

$$\text{Volume of Pressure Hull} = \frac{\pi D^3}{6} = \frac{(6.834)^3}{6} = 167\ ft.^3$$

where D = inside diameter of ALVIN pressure sphere (ft.)
Assume the entrained water volume = 90% of the pressure hull volume = .9(167) = 150 ft.^{3}
Then weight of entrained water = 64 x 150 = 9600 lbs.

$$m = \frac{W}{g} + \left(\frac{9600 + 24{,}300}{32.2}\right) = \frac{W}{g} + 1050 \tag{7}$$

Determination of Damping Factor

The force due to damping can be expressed as

$$F_D = \frac{1}{2}\, C_D\ \rho\, S\, (\dot{x})^2 \tag{8}$$

where C_D = coefficient of drag

S = projected area of ALVIN

ρ = density of salt water

Assume $C_D = 2$

$$S = .8\,\underbrace{(22)}_{\text{ALVIN length}}\,\underbrace{(8)}_{\text{ALVIN beam}} = 141\ ft.^2$$

$$\rho \approx 2\ \frac{lbs - sec^2}{ft.^4}$$

Substituting into eq. (8),

$$F_D = 282\,(\dot{x})^2$$

Using Taylor series linearization,

$$F_D \approx 564\,\left|\dot{x}_0\right|\,\dot{x} \tag{9}$$

where $\dot{x}_0$ = average velocity

Therefore, the damping coefficient, C, can be expressed as,

$$C \approx 564\,\left|\dot{x}_0\right| \tag{10}$$

Since the winch haul-in velocity is 35 ft./min., x is assumed to be,

$$\dot{x}_0 = \frac{35}{60} = .584\ ft./sec.$$

$$\therefore C = 564\,(.584) = 329\ lb. - sec./ft.$$

$$\zeta = \frac{C}{2m\omega_n} = \frac{164.5}{m\omega_n} \tag{11}$$

Determination of Linearized Spring Constants

Four different nylon ropes are considered in this report. These are:

4½-inch circumference Plimoor nylon rope
8-inch circumference Plimoor nylon rope

4½-inch circumference Samson 2-in-1 nylon rope
8-inch circumference Samson 2-in-1 nylon rope

The curve for nylon rope in figure D-6 shows the typical load versus elongation curve for Plimoor nylon rope. Curve B of figure D-7 shows the typical load versus elongation characteristic of Samson 2-in-1 nylon rope. The linearized spring constant of the rope is the slope of the load-elongation curve at the static load (ALVIN weight in water) point. From figures D-6 and D-7, linearized spring constants for the four nylon ropes specified above were determined as given in table 1.

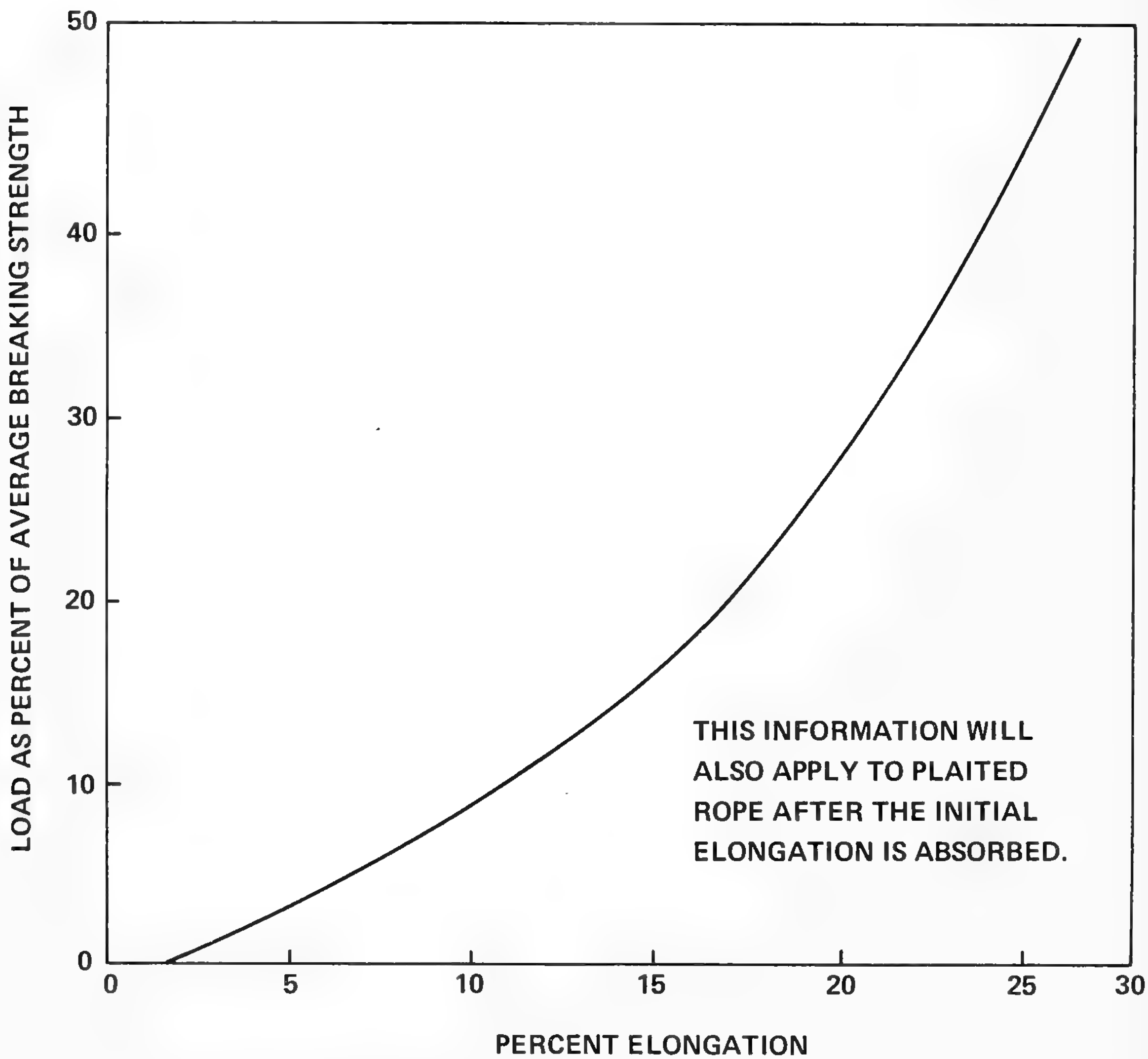


Figure D-6. Typical Elongation of Plimoor Nylon Rope After First Loading to 50% of Strength.

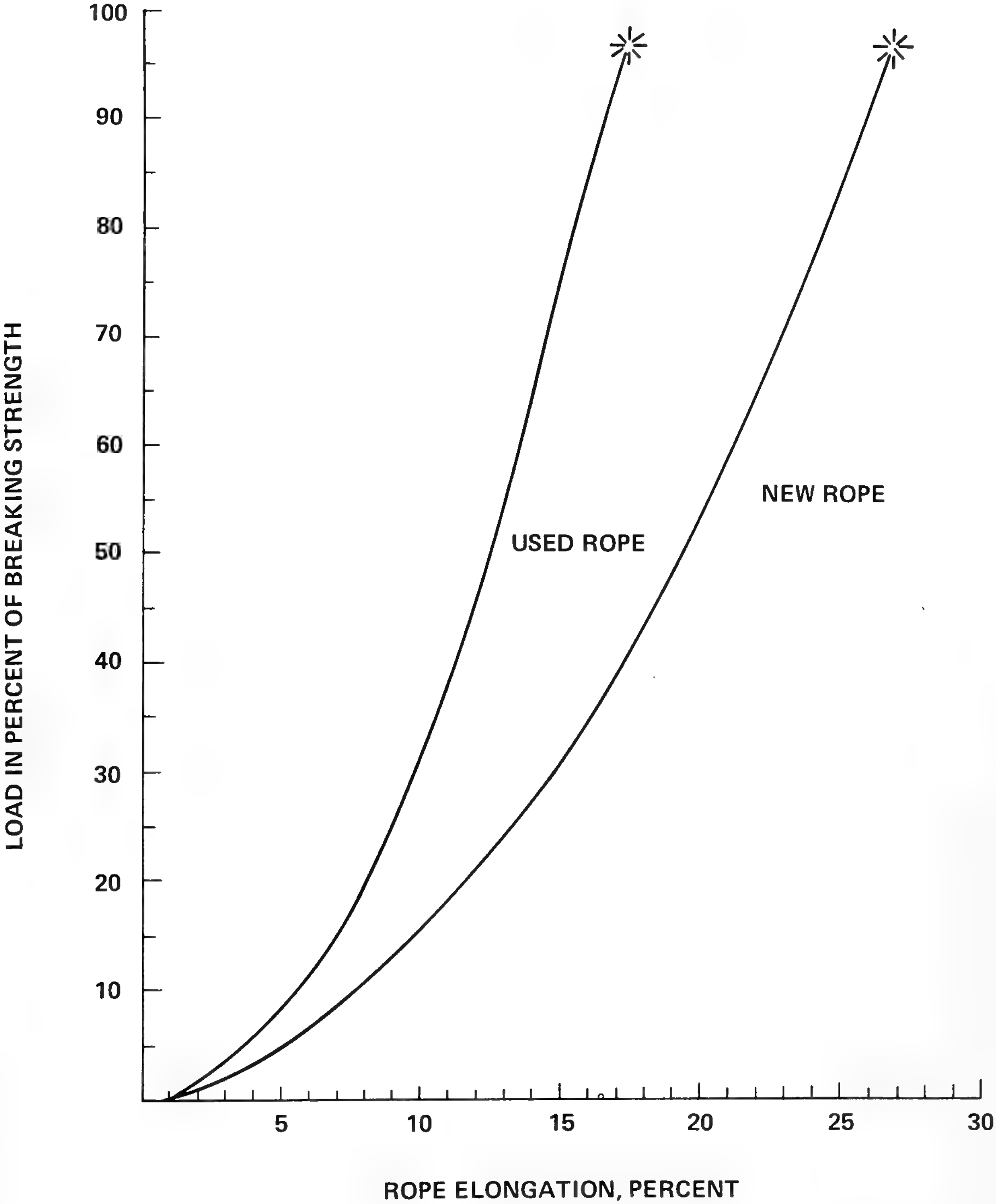


Figure D-7. Load-Elongation Curves for New and Used Samson 2-in-1 Nylon Rope.

Table 1. Linearized Spring Constants of Various Types and Sizes of Nylon Rope.

Static Load (wt. of ALVIN in water)	4½-inch Plimoor	8-inch Plimoor	4½-inch Samson 2-in-1	8-inch Samson 2-in-1
9,000–10,000 pounds	$\frac{99{,}000}{L}$	$\frac{176{,}300}{L}$	$\frac{358{,}000}{L}$	$\frac{440{,}000}{L}$
12,000 pounds	$\frac{132{,}000}{L}$	$\frac{190{,}000}{L}$	$\frac{419{,}000}{L}$	$\frac{546{,}000}{L}$
18,000 pounds	$\frac{175{,}400}{L}$	$\frac{216{,}000}{L}$	$\frac{500{,}000}{L}$	$\frac{656{,}000}{L}$

L = free, unloaded length of rope in feet

System Natural Frequency

The linearized spring constant can be expressed as

$$k = \frac{\psi(\text{rope, static load})}{L} \tag{12}$$

where ψ = constant based on the type of rope and static load point. Various values of ψ are given in table 1.

and L = free, unloaded length of rope (feet)

Using eq. (12), the equation for natural frequency becomes,

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{\psi}{mL}} \tag{13}$$

and m is given by eq. (7).

MIZAR Motions

MIZAR ship motions were supplied by NAVSEC Code 6136 as follows:

Dimensions:

LBP = Length between perpendiculars = 266 *feet*

B = Beam = 51.5 *feet*

H = Full Load Draft = 19 *feet*

Ship Motion:

1) Heave. Heave and pitch periods are calculated using Kreitner's approximation. (DTMB Report 1235, Sept. 1958).

$$T_H = \sqrt{\frac{40H + 10B}{g}} = \sqrt{\frac{40\,(19) + 10\,(51.5)}{32.2}} = 6.3 \text{ sec.}$$

$T_H \approx 6$ *seconds*

Sea State	Y_R *(1/3 highest amplitude)*
1	± 1 foot
2	± 2 feet
3	± 3 feet

2) Roll

T_R = Roll period = 10-11 seconds (MIZAR has anti-roll tanks)

Sea State	Y_R *(1/3 highest amplitude)*
3	$\pm 5^o$
5	$\pm 9^o$

3) Pitch

T_P = pitch period = *6 seconds*

Sea State	Y_P *(1/3 highest amplitude)*
3	$\pm 2^o$
5	$\pm 4^o$

Determination of Vertical Ship Motion Due to Heave, Roll, and Pitch

1) Lift rope deployed through MIZAR center well.

The center well of the MIZAR is approximately at the center of roll and pitch of the ship. Consequently, motion due to roll and pitch are approximately equal to zero.

$$y_H = Y_H \sin \left(\frac{2\pi}{T_H}\right) t$$

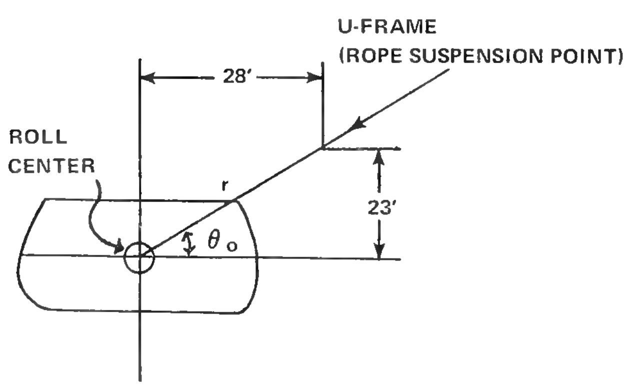
$$y_R = y_P = 0$$

2) Lift rope deployed over U-frame located at station 40 on MIZAR's main deck. All motions are for sea state 3.

Heave Motion

$$y_H = 3 \sin \left(\frac{2\pi}{6}\right) t = 3 \sin 1.04\, t$$

Vertical Motion Due to Roll



$$r = \sqrt{23^2 + 28^2} = 36.4'$$

$$\theta_0 = \tan^{-1} \frac{23}{28} = 39.4^o$$

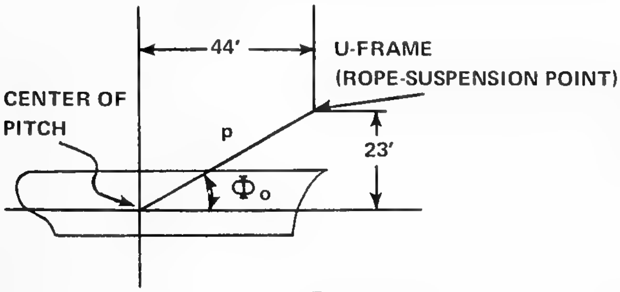
$$Y_R = r \left[\sin(\theta_0 + \theta_R) - \sin \theta_0\right]$$

from Section G, for sea state 3, $\theta_R = \pm 5^o$

$$\therefore Y_R = 36.4 \left[\sin(39.4^o + 5^o) - \sin 39.4^o\right]$$

$$Y_R = 2.365 \text{ ft.}$$

Vertical Motion Due to Pitch



$$p = \sqrt{(44)^2 + (23)^2} = 49.7'$$

$$\Phi_0 = \tan^{-1} \frac{23}{44} = 27.6^0$$

$$Y_p = p \left[\sin\,(\Phi_p + \Phi_0) - \sin,\Phi_0 \right]$$

from Section G, for sea state 3, $\Phi_p = \underline{+}2^0$

$$Y_p = 49.7 \left[\sin\,(27.6^0 + 2^0) - \sin 27.6^0 \right]$$

$$Y_p = 1.54 \text{ ft.}$$

Computations

The curves shown in figures D-1 through D-4 were plotted using data generated by a computer program based on the above analysis. Table 2 shows a typical set of calculations for plotting line tension versus line length curves.

CONCLUSIONS AND RECOMMENDATIONS

The results of the dynamic analysis performed in this study indicate that 4½-inch circumference Plimoor nylon rope will be suitable for lifting ALVIN in sea states less than 3. For this condition, lift line loads will not exceed 15,000 pounds for line lengths greater than 150 feet. NAVSEC evaluation of the 4½-inch Plimoor rope indicates that loads of this magnitude are permissible under the short time operating conditions anticipated in this application. A 15,000 pound maximum load provides a factor of safety of 3 based on the breaking strength of 45,000 pounds.

Based on the analysis performed, it is recommended that a load cell (tensionometer) be provided in the rope system to monitor the lift line loads at all times since it is apparent that severe resonant conditions could develop under the right conditions. The load cell used should be sensitive enough to measure transient dynamic loads as well as static tension.

Table 2. Sample Calculations.

$W = 9{,}000$ $\qquad K = \dfrac{99{,}000}{L}$ $\qquad$ 4½-inch Plimoor

	1	2	3	4	5	6	7	8	9	10
L	m	ω_n	ζ	$(2\zeta)^2$	$\left(\dfrac{\omega_p}{\omega_n}\right)^2$	$\left\lvert\dfrac{Z}{Y}\right\rvert_P$	Z_{P+H}	K	KZ	T_{max}
40	1330	1.365	.0908	.033	.852	3.82	21.15	2480	52500	61500
47	1330	1.26	.0984	.0388	1.00	5.18	28.7	2110	60600	69600
50	1330	1.22	.1016	.0412	1.07	4.92	27.2	1982	53900	62900
100	1330	.863	.144	.083	2.13	1.80	9.96	990	9850	18850
200	1330	.61	.2035	.165	4.18	1.3	7.20	495	3560	12360
500	1330	.386	.321	.412	10.67	1.1	6.09	198	1205	10205
1000	1330	.272	.456	.832	21.5	1.06	5.86	99	580	9580
5000	1330	.126	.984	3.88	100	1.0	5.54	19.8	110	9110

Assume Head Seas

∴ Motion due to roll ≈ 0 (computer program includes roll)

1 $\quad m = \dfrac{9{,}000}{32.2} + 1050 = 1330$ (eq. 7)

2 $\quad \omega_n = \sqrt{\dfrac{999{,}000}{1330\,L}} = \sqrt{\dfrac{74.5}{L}}$ (eq. 13)

3 $\quad \zeta = \dfrac{C}{2m\omega_n} = \dfrac{164.5}{2m\omega_n} = \dfrac{.124}{\omega_n}$ (eq. 11)

6 $\quad \left\lvert\dfrac{Z}{Y}\right\rvert_P$ (eq. 4)

7 $\quad Z_{P+H} = (\underbrace{4.0}_{\text{heave (ft)}} + \underbrace{1.54}_{\text{pitch (ft)}}) \left\lvert\dfrac{Z}{Y}\right\rvert_P$

8 $\quad K = \dfrac{99{,}000}{L}$ (Table 2)

10 $\quad T_{max} = 9{,}000 + KZ_{P+H}$ (eq. 5)

To provide a ready indication of sea conditions as well as data for use in future situations of this kind, it is recommended that a means for monitoring and recording ships motion be provided aboard MIZAR. In addition, the time variation of line load and ship motion should be recorded for use in verifying the mathematical models used to predict line loads.

Since the analysis indicates that resonance conditions could develop at lift line lengths less than 150 feet, it is recommended that extreme caution be exercised and that the lift line load be carefully watched when the lift line length is less than 200 feet.

Section 2

Calculations By Naval Research Laboratory

Studies were made by the Naval Research Laboratory to determine static and dynamic loads generated by ship motions for three types of line:

4½-inch-circumference nylon rope

8-inch-circumference polypropylene rope

0.7-inch-diameter steel cable.

This static load was assumed to be 10,000 pounds. Calculations (based on A.D. Little Report No. 3030365 of March 1965) were conducted for (1) retrieval of a mass through the center well of the ship; and (2) retrieval over the side — approximately 27 feet off the centerline.

These calculations showed that:

1. Using a larger line caused the peak loads to be larger.

2. Steel cable produced its fundamental resonance at a length greater than either nylon or polypropylene lines.

3. Lifting through the center well of the ship was found to be the safest mode of retrieval. (The overside lifting capacity was limited to 30,000 pounds.)

4. The line exhibiting the shortest fundamental resonant length was chosen for the lift.

The program, shown on page 79 of this appendix, was written in BASIC computer language, and was used in solving for the dynamic and static loads from the equations:

$$\left|\frac{U}{U_o}\right| = \left(\frac{U_a}{U_o}\right)^2 \left[\left(\cos kL - \frac{km}{\rho s} \sin kL\right)^2 + \left(\frac{km\beta}{\rho s}\right)^2 \left(\frac{U_a}{U_o}\right)^2 U_o{}^2 \sin^2 kL\right]$$

and

$$\left|\frac{\sigma}{U_o}\right| = \left\{E^2 k^2 \left(\frac{U_a}{U_o}\right)^2 \left[\left(\sin ky + \frac{km}{\rho s} \cos ky\right)^2 + \left(\frac{km\beta}{\rho s}\right)^2 \left(\frac{U_a}{U_o}\right)^2 U_o{}^2 \cos^2 ky\right]\right\}^{1/2}$$

$$\left|\frac{U_a}{U_o}\right| = 1 \quad when \quad y = L$$

where:

σ = stress value (lb/in^2)

U = dynamic extension of line

U_o = amplitude motion of the line at the surface end (ft)

E = modulus of elasticity for the line (lb/in^2)

k = wave number = $\frac{\omega}{c}$

where: ω = frequency of ship's roll (cycles/sec)

c = speed of sound of line (ft/sec)

U_a = amplitude of motion of line at some point along cable (ft)

y = length along line (ft)

m = mass of ALVIN at end of line (slugs)

ρ = density of line (slugs)

S = material cross-sectional area of the line (ft^2)

β = Constant

$$\frac{\frac{4}{3\pi}\,(C_D\,\rho_W\,A)}{m}$$

C_D = coefficient of drag

$$\frac{C_D\,\rho_W\,A\,V^2}{2}$$

A = projected area of load (ALVIN) (ft^2)

ρ_W = density of seawater (slugs)

NOTE:

(1) Data sheets in this appendix indicate the loads and stresses imposed on the three lines when the vertical amplitude, U_o, and period of oscillation, T, are varied.

(2) The accompanying graphs are plots of total loads taken from the same data sheets.

```
10 READ C,E,A3,R,S
15 I=0
20 READ M
30 READ D
40 B1=4*D*R*A3/(M*3*PI)
50 READ U
60 READ T
70 W=2*PI/T
80 K=W/C
85 READ R1
90 READ L
100 A1=K*M*B1/(R1*S)
105 A2=A1/B1
110 P=K*L
120 A=(CØS(P)-A2*SIN(P))↑2
130 B=(A1*U*SIN(P))↑2
140 F=SQR((A/(2*B))↑2+1/B)-A/(2*B)
142 IF I<>Ø GØ TØ 210
150 PRINT "C","E","A","RHØ","S"
160 PRINT C,E,A3,R,S
170 PRINT "M="M,"CD="D,"RHØ-CABLE="R1
180 PRINT "UØ="U,"T="T
190 PRINT
200 PRINT "LENGTH","DYNAMIC LØAD","TØTAL LØAD","TØTAL STRESS"
210 Y=L
220 Q=K*Y
240 S1=(SIN(Q)+A2*CØS(Q))↑2
250 S1=S1+F*(A1*U*CØS(Q))↑2
260 S1=E*K*U*SQR(F*S1)
265 S1=S1/144
266 L2=S1*S*144
267 L3=L2+10000
268 S2=L3/(S*144)
270 PRINT L,L2,L3,S2
280 I=1
300 GØ TØ 90
310 DATA 11200,2.16E+09,155.5,1.98,1.03E-03
320 DATA 1700
330 DATA 1.0
340 DATA 7
350 DATA 9
355 DATA 13.4
360 DATA 50,75,100,200,300,400,500,600,700,800,900,1000
361 DATA 1200,1400,1600,1800,2000,2200,2400,2600,2800,3000
362 DATA 3200,3400,3600,3800,4000
370 END

>
```

REM THE FØLLØWING 9 SETS ARE FØR THE 4.5" NYLØN CABLE

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 2	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	21539	31539	23635.3
75	19999.8	29999.8	22481.9
100	13455.9	23455.9	17577.9
200	4023.22	14023.2	10509
300	2291.78	12291.8	9211.47
400	1596.92	11596.9	8690.74
500	1221.89	11221.9	8409.69
600	986.572	10986.6	8233.34
700	824.694	10824.7	8112.03
800	706.159	10706.2	8023.2
900	615.335	10615.3	7955.14
1000	543.297	10543.3	7901.15
1200	435.632	10435.6	7820.47
1400	358.244	10358.2	7762.47
1600	299.211	10299.2	7718.23
1800	252.106	10252.1	7682.93
2000	213.149	10213.1	7653.74
2200	179.967	10180	7628.87
2400	150.987	10151	7607.15
2600	125.118	10125.1	7587.77
2800	101.57	10101.6	7570.12
3000	79.7531	10079.8	7553.77
3200	59.2051	10059.2	7538.37
3400	39.551	10039.6	7523.64
3600	20.4723	10020.5	7509.35
3800	1.68497	10001.7	7495.27
4000	17.0791	10017.1	7506.8

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 2	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	6529.76	16529.8	12387.4
75	8891.51	18891.5	14157.3
100	11107.1	21107.1	15817.6
200	6622.63	16622.6	12457
300	3148.3	13148.3	9853.34
400	1989.36	11989.4	8984.83
500	1447.51	11447.5	8578.77
600	1135.35	11135.3	8344.83
700	932.381	10932.4	8192.73
800	789.694	10789.7	8085.8
900	683.759	10683.8	8006.41
1000	601.874	10601.9	7945.05
1200	483.216	10483.2	7856.13
1400	400.968	10401	7794.49
1600	340.226	10340.2	7748.97
1800	293.232	10293.2	7713.75
2000	255.553	10255.6	7685.52
2200	224.466	10224.5	7662.22
2400	198.208	10198.2	7642.54
2600	175.584	10175.6	7625.59
2800	155.757	10155.8	7610.73
3000	138.118	10138.1	7597.51
3200	122.218	10122.2	7585.59
3400	107.711	10107.7	7574.72
3600	94.3319	10094.3	7564.7
3800	81.8669	10081.9	7555.36
4000	70.1447	10070.1	7546.57

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 2	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	3190.98	13191	9885.33
75	3746.16	13746.2	10301.4
100	4489.65	14489.6	10858.5
200	6901.09	16901.1	12665.7
300	4725.4	14725.4	11035.2
400	2806.09	12806.1	9596.89
500	1876.51	11876.5	8900.26
600	1393.51	11393.5	8538.3
700	1104.67	11104.7	8321.84
800	913.523	10913.5	8178.6
900	777.827	10777.8	8076.91
1000	676.495	10676.5	8000.97
1200	535.1	10535.1	7895.01
1400	440.894	10440.9	7824.41
1600	373.396	10373.4	7773.83
1800	322.47	10322.5	7735.66
2000	282.527	10282.5	7705.73
2200	250.235	10250.2	7681.53
2400	223.482	10223.5	7661.48
2600	200.865	10200.9	7644.53
2800	181.417	10181.4	7629.96
3000	164.445	10164.4	7617.24
3200	149.445	10149.4	7606
3400	136.037	10136	7595.95
3600	123.93	10123.9	7586.88
3800	112.899	10112.9	7578.61
4000	102.763	10102.8	7571.02

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 5	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	41965.9	51965.9	38943.3
75	34733	44733	33522.9
100	26105.7	36105.7	27057.6
200	9876.95	19877	14895.8
300	5709.71	15709.7	11772.9
400	3987.64	13987.6	10482.3
500	3053.1	13053.1	9782
600	2465.72	12465.7	9341.82
700	2061.38	12061.4	9038.8
800	1765.2	11765.2	8816.84
900	1538.22	11538.2	8646.75
1000	1358.16	11358.2	8511.81
1200	1089.04	11089	8310.13
1400	895.59	10895.6	8165.16
1600	748.016	10748	8054.57
1800	630.257	10630.3	7966.32
2000	532.867	10532.9	7893.34
2200	449.914	10449.9	7831.17
2400	377.465	10377.5	7776.88
2600	312.791	10312.8	7728.41
2800	253.923	10253.9	7684.29
3000	199.381	10199.4	7643.42
3200	148.011	10148	7604.92
3400	98.876	10098.9	7568.1
3600	51.1794	10051.2	7532.36
3800	4.21385	10004.2	7497.16
4000	42.6996	10042.7	7526

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 5	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	17501.7	27501.7	20609.8
75	20894.3	30894.3	23152.2
100	21355.5	31355.5	23497.8
200	13001.5	23001.5	17237.4
300	7431.51	17431.5	13063.2
400	4891.21	14891.2	11159.5
500	3595	13595	10188.1
600	2829.27	12829.3	9614.26
700	2326.78	12326.8	9237.69
800	1972.06	11972.1	8971.87
900	1708.15	11708.2	8774.09
1000	1503.92	11503.9	8621.04
1200	1207.7	11207.7	8399.06
1400	1002.25	11002.2	8245.09
1600	850.465	10850.5	8131.34
1800	733.02	10733	8043.33
2000	638.842	10638.8	7972.75
2200	561.137	10561.1	7914.52
2400	495.499	10495.5	7865.33
2600	438.945	10438.9	7822.95
2800	389.38	10389.4	7785.81
3000	345.286	10345.3	7752.76
3200	305.537	10305.5	7722.97
3400	269.272	10269.3	7695.8
3600	235.824	10235.8	7670.73
3800	204.662	10204.7	7647.38
4000	175.358	10175.4	7625.42

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
U0= 5	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	8645.01	18645	13972.6
75	10115.6	20115.6	15074.7
100	11614.5	21614.5	16197.9
200	12148.1	22148.1	16597.8
300	8794.88	18794.9	14084.9
400	6129.29	16129.3	12087.3
500	4438.58	14438.6	10820.3
600	3396.86	13396.9	10039.6
700	2725.74	12725.7	9536.68
800	2266.65	12266.7	9192.63
900	1935.43	11935.4	8944.42
1000	1685.95	11685.9	8757.46
1200	1335.62	11335.6	8494.92
1400	1101.22	11101.2	8319.26
1600	932.943	10932.9	8193.15
1800	805.852	10805.9	8097.91
2000	706.114	10706.1	8023.17
2200	625.451	10625.5	7962.72
2400	558.609	10558.6	7912.63
2600	502.094	10502.1	7870.27
2800	453.49	10453.5	7833.85
3000	411.074	10411.1	7802.06
3200	373.582	10373.6	7773.97
3400	340.067	10340.1	7748.85
3600	309.805	10309.8	7726.17
3800	282.23	10282.2	7705.51
4000	256.894	10256.9	7686.52

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 7	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	54008.9	64008.9	47968.3
75	43250	53250	39905.6
100	33072.4	43072.4	32278.5
200	13597.4	23597.4	17683.9
300	7964.08	17964.1	13462.3
400	5575.44	15575.4	11672.2
500	4271.78	14271.8	10695.3
600	3450.9	13450.9	10080.1
700	2885.36	12885.4	9656.3
800	2470.96	12471	9345.74
900	2153.31	12153.3	9107.7
1000	1901.3	11901.3	8918.84
1200	1524.6	11524.6	8636.54
1400	1253.79	11253.8	8433.6
1600	1047.2	11047.2	8278.78
1800	882.346	10882.3	8155.23
2000	746.005	10746	8053.06
2200	629.873	10629.9	7966.03
2400	528.446	10528.4	7890.02
2600	437.904	10437.9	7822.17
2800	355.489	10355.5	7760.41
3000	279.13	10279.1	7703.18
3200	207.213	10207.2	7649.29
3400	138.424	10138.4	7597.74
3600	71.649	10071.6	7547.7
3800	5.90167	10005.9	7498.43
4000	59.7826	10059.8	7538.81

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 7	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	25769.5	35769.5	26805.7
75	28451.3	38451.3	28815.4
100	27391.1	37391.1	28020.9
200	16508.9	26508.9	19865.8
300	9981.66	19981.9	14974.4
400	6741.64	16741.6	12546.2
500	4998.88	14998.9	11240.2
600	3947.33	13947.3	10452.1
700	3251.07	13251.1	9930.36
800	2757.49	12757.5	9560.47
900	2389.46	12389.5	9284.67
1000	2104.28	12104.3	9070.95
1200	1690.25	11690.2	8760.68
1400	1402.87	11402.9	8545.32
1600	1190.49	11190.5	8386.16
1800	1026.13	11026.1	8262.99
2000	894.315	10894.3	8164.2
2200	785.547	10785.5	8082.69
2400	693.666	10693.7	8013.84
2600	614.499	10614.5	7954.51
2800	545.113	10545.1	7902.51
3000	483.386	10483.4	7856.25
3200	427.739	10427.7	7814.55
3400	376.971	10377	7776.51
3600	330.145	10330.1	7741.42
3800	286.52	10286.5	7708.72
4000	245.494	10245.5	7677.98

C	E	A	RHØ	S
3000	2.88E+07	155.5	1.98	9.27E-03
M= 1700	CD= 1	RHØ-CABLE= 2.1891		
UØ= 7	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	13024.2	23024.2	17254.4
75	15036.5	25036.5	18762.4
100	16595	26595	19930.3
200	15231.5	25231.5	18908.5
300	11057.6	21057.6	15780.6
400	7987.39	17987.4	13479.8
500	5967.98	15968	11966.4
600	4651.5	14651.5	10979.8
700	3768.01	13768	10317.8
800	3148.95	13149	9853.83
900	2696.16	12696.2	9514.51
1000	2352.38	12352.4	9256.88
1200	1866.59	11866.6	8892.83
1400	1540.12	11540.1	8648.17
1600	1305.26	11305.3	8472.16
1800	1127.68	11127.7	8339.09
2000	988.235	10988.2	8234.59
2200	875.415	10875.4	8150.04
2400	781.902	10781.9	8079.96
2600	702.822	10702.8	8020.7
2800	634.804	10634.8	7969.73
3000	575.44	10575.4	7925.24
3200	522.965	10523	7885.91
3400	476.055	10476.1	7850.76
3600	433.694	10433.7	7819.02
3800	395.094	10395.1	7790.09
4000	359.628	10359.6	7763.51

REM THE FØLLØWING 9 SETS ARE FØR THE 8" PØLYPRØP CABLE

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 2	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	11935.8	21935.8	4315.34
75	14738	24738	4866.62
100	18571.4	28571.4	5620.75
200	21476.7	31476.7	6192.3
300	11540.5	21540.5	4237.58
400	6794.88	16794.9	3304
500	4708.2	14708.2	2893.49
600	3579.81	13579.8	2671.51
700	2875.89	12875.9	2533.03
800	2394.21	12394.2	2438.27
900	2042.9	12042.9	2369.16
1000	1774.48	11774.5	2316.35
1200	1388.93	11388.9	2240.5
1400	1122.39	11122.4	2188.07
1600	924.378	10924.4	2149.11
1800	769.28	10769.3	2118.6
2000	642.675	10642.7	2093.7
2200	535.799	10535.8	2072.67
2400	442.992	10443	2054.41
2600	360.401	10360.4	2038.17
2800	285.284	10285.3	2023.39
3000	215.6	10215.6	2009.68
3200	149.758	10149.8	1996.73
3400	86.4593	10086.5	1984.27
3600	24.5895	10024.6	1972.1
3800	36.9042	10036.9	1974.52
4000	98.9778	10099	1986. 4

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 2	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	5109.54	15109.5	2972.45
75	5583.85	15583.8	3065.76
100	6149.37	16149.4	3177.01
200	9686.64	19686.6	3872.88
300	12434.4	22434.4	4413.44
400	10763.2	20763.2	4084.68
500	7900.8	17900.8	3521.56
600	5653.8	15653.8	3079.52
700	4229.25	14229.2	2799.27
800	3331.81	13331.8	2622.72
900	2732.87	12732.9	2504.89
1000	2308.82	12308.8	2421.47
1200	1750.36	11750.4	2311.61
1400	1398.54	11398.5	2242.4
1600	1155.35	11155.4	2194.55
1800	976.042	10976	2159.28
2000	837.402	10837.4	2132
2200	726.199	10726.2	2110.13
2400	634.343	10634.3	2092.06
2600	556.604	10556.6	2076.76
2800	489.451	10489.5	2063.55
3000	430.407	10430.4	2051.94
3200	377.678	10377.7	2041.56
3400	329.931	10329.9	2032.17
3600	286.15	10286.1	2023.56
3800	245.539	10245.5	2015.57
4000	207.465	10207.5	2008.08

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 2	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	2897.71	12897.7	2537.32
75	3046.12	13046.1	2566.52
100	3209.98	13210	2598.75
200	4071.64	14071.6	2768.26
300	5396.87	15396.9	3028.97
400	6935.35	16935.3	3331.63
500	7560.19	17560.2	3454.56
600	7097.07	17097.1	3363.45
700	6118.4	16118.4	3170.92
800	5044.77	15044.8	2959.7
900	4099.22	14099.2	2773.69
1000	3356.41	13356.4	2627.56
1200	2381.7	12381.7	2435.81
1400	1815.31	11815.3	2324.38
1600	1455.37	11455.4	2253.58
1800	1207.79	11207.8	2204.87
2000	1026.92	11026.9	2169.29
2200	888.61	10888.6	2142.08
2400	779.007	10779	2120.52
2600	689.648	10689.6	2102.94
2800	615.075	10615.1	2088.27
3000	551.617	10551.6	2075.78
3200	496.712	10496.7	2064.98
3400	448.517	10448.5	2055.5
3600	405.675	10405.7	2047.07
3800	367.161	10367.2	2039.49
4000	332.185	10332.2	2032.61

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 5	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	32378.8	42378.8	8337.04
75	38908.7	48908.7	9621.63
100	43996.4	53996.4	10622.5
200	37311.6	47311.6	9307.44
300	24082.5	34082.5	6704.93
400	15986.9	25986.9	5112.31
500	11498.9	21498.9	4229.4
600	8852.88	18852.9	3708.86
700	7147.79	17147.8	3373.42
800	5964.54	15964.5	3140.65
900	5095.59	15095.6	2969.7
1000	4429.17	14429.2	2838.6
1200	3469.29	13469.3	2649.77
1400	2804.41	12804.4	2518.97
1600	2310.05	12310	2421.71
1800	1922.63	11922.6	2345.5
2000	1606.3	11606.3	2283.27
2200	1339.22	11339.2	2230.72
2400	1107.27	11107.3	2185.09
2600	900.833	10900.8	2144.48
2800	713.071	10713.1	2107.54
3000	538.882	10538.9	2073.28
3200	374.294	10374.3	2040.9
3400	216.07	10216.1	2009.77
3600	61.4877	10061.5	1979.36
3800	92.4541	10092.5	1985.45
4000	247.591	10247.6	2015.97

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 5	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	13735.9	23735.9	4669.48
75	15108.4	25108.4	4939.49
100	16676	26676	5247.87
200	22640.6	32640.6	6421.27
300	22350.6	32350.6	6364.22
400	18756.5	28756.5	5657.17
500	15023.8	25023.8	4922.84
600	11948.2	21948.2	4317.79
700	9608.86	19608.9	3857.58
800	7882.4	17882.4	3517.94
900	6607.8	16607.8	3267.19
1000	5650.19	15650.2	3078.81
1200	4332.01	14332	2819.49
1400	3477.03	13477	2651.29
1600	2878.54	12878.5	2533.55
1800	2434.53	12434.5	2446.2
2000	2090.08	12090.1	2378.44
2200	1813.25	11813.2	2323.98
2400	1584.3	11584.3	2278.94
2600	1390.39	11390.4	2240.79
2800	1222.78	11222.8	2207.82
3000	1075.36	11075.4	2178.82
3200	943.673	10943.7	2152.91
3400	824.402	10824.4	2129.45
3600	715.018	10715	2107.93
3800	613.544	10613.5	2087.97
4000	518.4	10518.4	2069.25

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
U0= 5	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	7741.8	17741.8	3490.28
75	8176.34	18176.3	3575.77
100	8653.62	18653.6	3669.66
200	10979.2	20979.2	4127.16
300	13291.8	23291.8	4582.11
400	14134.5	24134.5	4747.89
500	13521.3	23521.3	4627.27
600	12248.4	22248.4	4376.86
700	10813.9	20813.9	4094.65
800	9437	19437	3823.77
900	8202.99	18203	3581.01
1000	7137.57	17137.6	3371.41
1200	5488.17	15488.2	3046.93
1400	4348.21	14348.2	2822.67
1600	3550.97	13551	2665.84
1800	2974.58	12974.6	2552.44
2000	2542.08	12542.1	2467.36
2200	2206.26	12206.3	2401.3
2400	1937.72	11937.7	2348.46
2600	1717.5	11717.5	230[illegible].14
2800	1533.03	11533	2268.[illegible]5
3000	1375.65	11375.6	2237.89
3200	1239.23	11239.2	2211.05
3400	1119.32	11119.3	2187.47
3600	1012.63	11012.6	2166.48
3800	916.647	10916.6	2147.59
4000	829.431	10829.4	2130.44

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 7	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	48636.1	58636.1	11535.3
75	56461	66461	13074.0
100	60097.8	70097.8	13790.1
200	46447.8	56447.8	11104.8
300	30988.5	40988.5	8063.52
400	21435.4	31435.4	6184.17
500	15767.2	25767.2	5069.09
600	12261.6	22261.6	4379.44
700	9946.01	19946	3923.91
800	8318.91	18318.9	3603.81
900	7116.03	17116	3367.18
1000	6190	16190	3185
1200	4852.26	14852.3	2921.83
1400	3923.73	13923.7	2739.17
1600	3232.65	13232.6	2603.21
1800	2690.78	12690.8	2496.61
2000	2248.2	12248.2	2409.55
2200	1874.46	11874.5	2336.02
2400	1549.83	11549.8	2272.16
2600	1260.9	11260.9	2215.32
2800	998.077	10998.1	2163.61
3000	754.247	10754.2	2115.65
3200	523.853	10523.9	2070.32
3400	302.374	10302.4	2026.75
3600	86.1049	10086.[illegible]	1984.2
3800	129.744	10129.7	1992.79
4000	346.86	10346.9	2035.5

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 7	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	20636	30636	6026.92
75	22758.5	32758.5	6444.46
100	25028.5	35028.5	6891.02
200	30762	40762	8018.97
300	28175.3	38175.3	7510.1
400	23347.3	33347.3	6560.29
500	18952.1	28952.1	5695.64
600	15420	25420	5000.8
700	12686.7	22686.7	4463.07
800	10597.1	20597.1	4051.99
900	8997.06	18997.1	3737.23
1000	7758.59	17758.6	3493.58
1200	6003.97	16004	3148.4
1400	4839.58	14839.6	2919.34
1600	4015.14	14015.1	2757.15
1800	3399.81	13399.8	2636.1
2000	2920.81	12920.8	2541.87
2200	2535.05	12535	2465.98
2400	2215.59	12215.6	2403.13
2600	1944.77	11944.8	2349.85
2800	1710.57	11710.6	2303.78
3000	1504.47	11504.5	2263.23
3200	1320.32	11320.3	2227.01
3400	1153.49	11153.5	2194.19
3600	1000.46	11000.5	2164.08
3800	858.48	10858.5	2136.15
4000	725.344	10725.3	2109.96

C	E	A	RHØ	S
2800	2.16E+07	155.5	1.98	0.0353
M= 1700	CD= 1	RHØ-CABLE= 1.75		
UØ= 7	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	11579.4	21579.4	4245.24
75	12271.2	22271.2	4381.34
100	13020.2	23020.2	4528.67
200	16300.1	26300.1	5173.92
300	18467.6	28467.6	5600.33
400	18397.2	28397.2	5586.48
500	17019.4	27019.4	5315.44
600	15243.7	25243.7	4966.11
700	13477.4	23477.4	4618.63
800	11865.8	21865.8	4301.58
900	10448.2	20448.2	4022.7
1000	9223.85	19223.8	3781.84
1200	7285.74	17285.7	3400.56
1400	5885.17	15885.2	3125.03
1600	4864.73	14864.7	2924.29
1800	4104.95	14105	2774.82
2000	3523.71	13523.7	2660.47
2200	3066.74	13066.7	2570.57
2400	2698.33	12698.3	2498.1
2600	2394.58	12394.6	2438.34
2800	2139.18	12139.2	2388.1
3000	1920.71	11920.7	2345.12
3200	1730.99	11731	2307.8
3400	1564	11564	2274.95
3600	1415.27	11415.3	2245.69
3800	1281.35	11281.3	2219.34
4000	1159.59	11159.6	2195.39

REM THE FOLLOWING 9 SETS ARE FOR THE 0.7" DIAM STEEL CABLE

C	E	A	RHO	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHO-CABLE= 13.4		
U0= 2	T= 7			

LENGTH	DYNAMIC LOAD	TOTAL LOAD	TOTAL STRESS
50	3713.12	13713.1	92456.3
75	3793.83	13793.8	93000.5
100	3878.06	13878.1	93568.4
200	4255.09	14255.1	96110.4
300	4710.12	14710.1	99178.3
400	5266.07	15266.1	102927
500	5949.71	15949.7	107536
600	6781.6	16781.6	113145
700	7744.25	17744.3	119635
800	8729.78	18729.8	126280
900	9542.08	19542.1	131756
1000	10019.6	20019.6	134976
1200	9934.67	19934.7	134403
1400	8962.74	18962.7	127850
1600	7661.61	17661.6	119078
1800	6373.45	16373.4	110393
2000	5271.7	15271.7	102965
2200	4401.58	14401.6	97098.1
2400	3735.05	13735	92604.2
2600	3224.17	13224.2	89159.7
2800	2826.69	12826.7	86479.8
3000	2511.36	12511.4	84353.8
3200	2256.27	12256.3	82634
3400	2046.19	12046.2	81217.6
3600	1870.41	11870.4	80032.4
3800	1721.24	11721.2	79026.7
4000	1593.11	11593.1	78162.8

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 2	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	7584.65	17584.6	118559
75	7927.18	17927.2	120868
100	8301.41	18301.4	123391
200	10209.8	20209.8	136258
300	13048.8	23048.8	155399
400	16759.2	26759.2	180415
500	19447.3	29447.3	198539
600	19557.7	29557.7	199284
700	17860.5	27860.5	187841
800	15424	25424	171413
900	12929	22929	154592
1000	10740.8	20740.8	139838
1200	7621.4	17621.4	118807
1400	5759.99	15760	106257
1600	4593.25	14593.3	98390.3
1800	3807.49	13807.5	93092.6
2000	3245.53	13245.5	89303.8
2200	2824.46	12824.5	86464.8
2400	2497.3	12497.3	84259
2600	2235.73	12235.7	82495.5
2800	2021.71	12021.7	81052.5
3000	1843.21	11843.2	79849.1
3200	1691.96	11692	78829.3
3400	1562.04	11562	77953.4
3600	1449.14	11449.1	77192.2
3800	1350.04	11350	76524
4000	1262.26	11262.3	75932.2

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 2	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	2209.4	12209.4	82318
75	2237.91	12237.9	82510.2
100	2267.16	12267.2	82707.4
200	2392.01	12392	83549.2
300	2531.01	12531	84486.3
400	2686.52	12686.5	85534.8
500	2861.37	12861.4	86713.7
600	3058.83	13058.8	88044.9
700	3282.54	13282.5	89553.3
800	3536.25	13536.3	91263.8
900	3822.99	13823	93197.1
1000	4143.57	14143.6	95358.5
1200	4861.93	14861.9	100202
1400	5556.6	15556.6	104885
1600	6019.31	16019.3	108005
1800	6154.8	16154.8	108919
2000	6010.1	16010.1	107943
2200	5676.8	15676.8	105696
2400	5236.16	15236.2	102725
2600	4749.28	14749.3	99442.3
2800	4260.15	14260.2	96144.5
3000	3798.77	13798.8	93033.8
3200	3382.79	13382.8	90229.2
3400	3019.26	13019.3	87778.2
3600	2707.49	12707.5	85676.2
3800	2442.45	12442.4	83889.2
4000	2217.45	12217.5	82372.2

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 5	T= 5			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	20248.9	30248.9	203944
75	21255.3	31255.3	210729
100	22351.5	32351.5	218120
200	27661.6	37661.6	253922
300	33493	43493	293238
400	36855.7	46855.7	315909
500	36619.3	46619.3	314316
600	34203.7	44203.7	298029
700	30952.1	40952.1	276106
800	27571.9	37571.9	253317
900	24382.2	34382.2	231811
1000	21513.2	31513.2	212468
1200	16850.8	26850.8	181033
1400	13474	23474	158266
1600	11059	21059	141984
1800	9305.31	19305.3	130160
2000	7997	17997	121339
2200	6992.49	16992.5	114566
2400	6200.5	16200.5	109227
2600	5561.38	15561.4	104918
2800	5035.24	15035.2	101370
3000	4594.63	14594.6	98399.6
3200	4220.18	14220.2	95875
3400	3897.88	13897.9	93702
3600	3617.38	13617.4	91810.8
3800	3370.85	13370.8	90148.7
4000	3152.31	13152.3	88675.2

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 5	T= 7			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	9871.01	19871	133974
75	10107.5	20107.5	135569
100	10354.7	20354.7	137235
200	11459.3	21459.3	144683
300	12764.6	22764.6	153483
400	14256.1	24256.1	163539
500	15832.4	25832.4	174166
600	17277.9	27277.9	183912
700	18344.2	28344.2	191102
800	18896.3	28896.3	194824
900	18956	28956	195226
1000	18631.3	28631.3	193037
1200	17290.9	27290.9	184000
1400	15565.7	25565.7	172369
1600	13804.9	23804.9	160497
1800	12161.9	22161.9	149419
2000	10696.7	20696.7	139541
2200	9425.15	19425.1	130968
2400	8340.15	18340.2	123653
2600	7423.29	17423.3	117471
2800	6651.4	16651.4	112267
3000	6000.97	16001	107881
3200	5450.59	15450.6	104171
3400	4981.97	14982	101011
3600	4580.01	14580	98301.1
3800	4232.57	14232.6	95958.6
40C0	3929.93	13929 9	93918.1

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 5	T= 9			

LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	5863.46	15863.5	106954
75	5946.77	15946.8	107516
100	6032.32	16032.3	108093
200	6398.21	16398.2	110560
300	6805.13	16805.1	113303
400	7256.46	17256.5	116346
500	7753.37	17753.4	119696
600	8292.59	18292.6	123332
700	8863.58	18863.6	127182
800	9445.87	19445.9	131108
900	10009	20009	134904
1000	10516.9	20516.9	138328
1200	11245.2	21245.2	143239
1400	11513.6	21513.6	145049
1600	11385.2	21385.2	144183
1800	10988.1	20988.1	141505
2000	10435.4	20435.4	137779
2200	9806.63	19806.6	133540
2400	9152.38	19152.4	129129
2600	8503.83	18503.8	124756
2800	7879.59	17879.6	120547
3000	7290.35	17290.4	116575
3200	6741.81	16741.8	112876
3400	6236.39	16236.4	109469
3600	5774.34	15774.3	106353
3800	5354.44	15354.4	103522
4000	4974.45	14974.4	100960

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 7	T= 5			

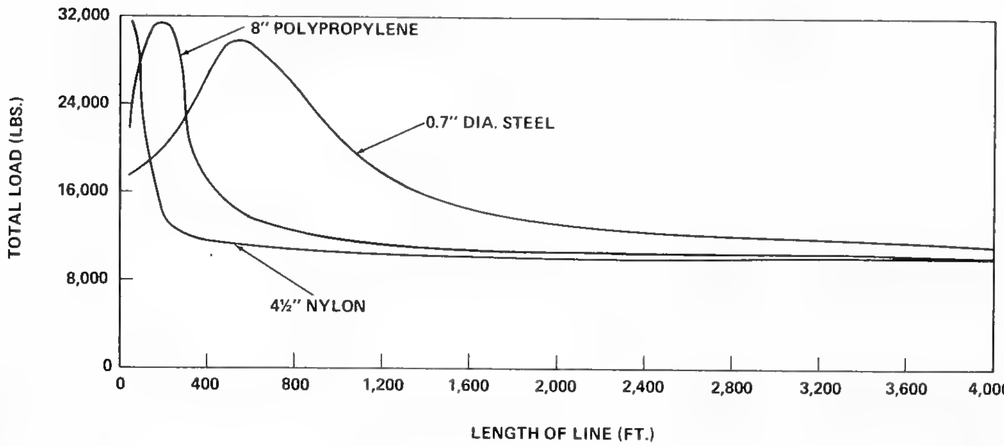
LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	30268.9	40268.9	271500
75	31878	41878	282349
100	33611.9	43611.9	294039
200	41367.5	51367.5	346329
300	47610.4	57610.4	388420
400	49045.9	59045.9	398098
500	46718.9	56718.9	382409
600	42800.8	52800.8	355992
700	38531.5	48531.5	327208
800	34440.7	44440.7	299627
900	30721.8	40721.8	274553
1000	27425.3	37425.3	252328
1200	22041.1	32041.1	216027
1400	18016.1	28016.1	188890
1600	15019.1	25019.1	168683
1800	12765.9	22765.9	153492
2000	11041.6	21041.6	141866
2200	9694.36	19694.4	132783
2400	8619.43	18619.4	125536
2600	7744.93	17744.9	119640
2800	7020.95	17020.9	114758
3000	6412.24	16412.2	110654
3200	5893.44	15893.4	107156
3400	5445.94	15445.9	104139
3600	5055.85	15055.9	101509
3800	4712.6	14712.6	99195
4000	4408.02	14408	97141.5

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-0[illegible]
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 7	T= 7			

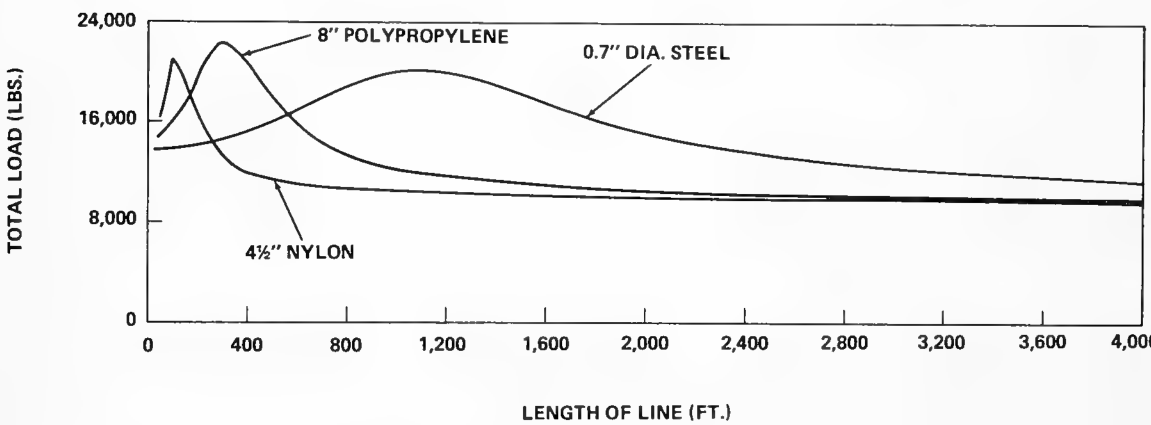
LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	14703.3	24703.3	166554
75	15083.5	25083.5	169118
100	15480.2	25480.2	171792
200	17234	27234	183617
300	19222	29222	197020
400	21291.8	31291.8	210975
500	23142.6	33142.6	223453
600	24448.5	34448.5	232258
700	25055.6	35055.6	236351
800	25022.7	35022.7	236129
900	24512.6	34512.6	232690
1000	23692.1	33692.1	227158
1200	21602.3	31602.3	213068
1400	19373.2	29373.2	198039
1600	17260.4	27260.4	183795
1800	15353.3	25353.3	170937
2000	13671.9	23671.9	159600
2200	12208.2	22208.2	149732
2400	10943.3	20943.3	141203
2600	9854.29	19854.3	133861
2800	8918.01	18918	127549
3000	8112.4	18112.4	122117
3200	7417.45	17417.5	117432
3400	6815.67	16815.7	113374
3600	6292.08	16292.1	109844
3800	5834.07	15834.1	106756
4000	5431.18	15431.2	104040

C	E	A	RHØ	S
11200	2.16E+09	155.5	1.98	1.03E-03
M= 1700	CD= 1	RHØ-CABLE= 13.4		
UØ= 7	T= 9			

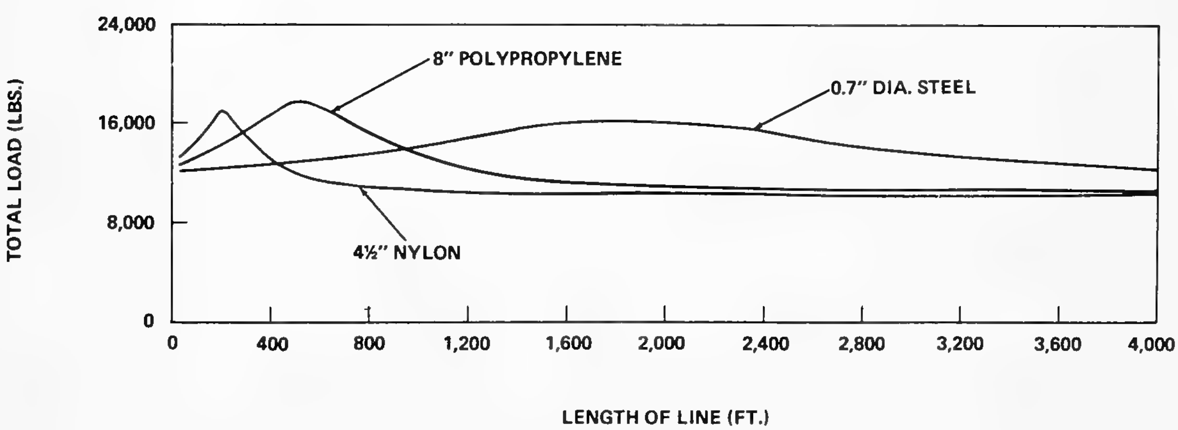
LENGTH	DYNAMIC LØAD	TØTAL LØAD	TØTAL STRESS
50	8720.85	18720.9	126219
75	8854.73	18854.7	127122
100	8992.16	18992.2	128049
200	9578.51	19578.5	132002
300	10224.4	20224.4	136357
400	10926.6	20926.6	141091
500	11672.7	21672.7	146121
600	12438	22438	151281
700	13183.8	23183.8	156309
800	13862.6	23862.6	160886
900	14428.4	24428.4	164700
1000	14848.4	24848.4	167532
1200	15218.6	25218.6	170029
1400	15054.8	25054.8	168924
1600	14537.7	24537.7	165437
1800	13825.6	23825.6	160636
2000	13025.5	23025.5	155242
2200	12202.4	22202.4	149693
2400	11393.6	21393.6	144240
2600	10619.5	20619.5	139020
2800	9890.29	19890.3	134104
3000	9210.53	19210.5	129521
3200	8581.24	18581.2	125278
3400	8001.48	18001.5	121369
3600	7469.23	17469.2	117781
3800	6981.8	16981.8	114494
4000	6536.19	16536.2	111490



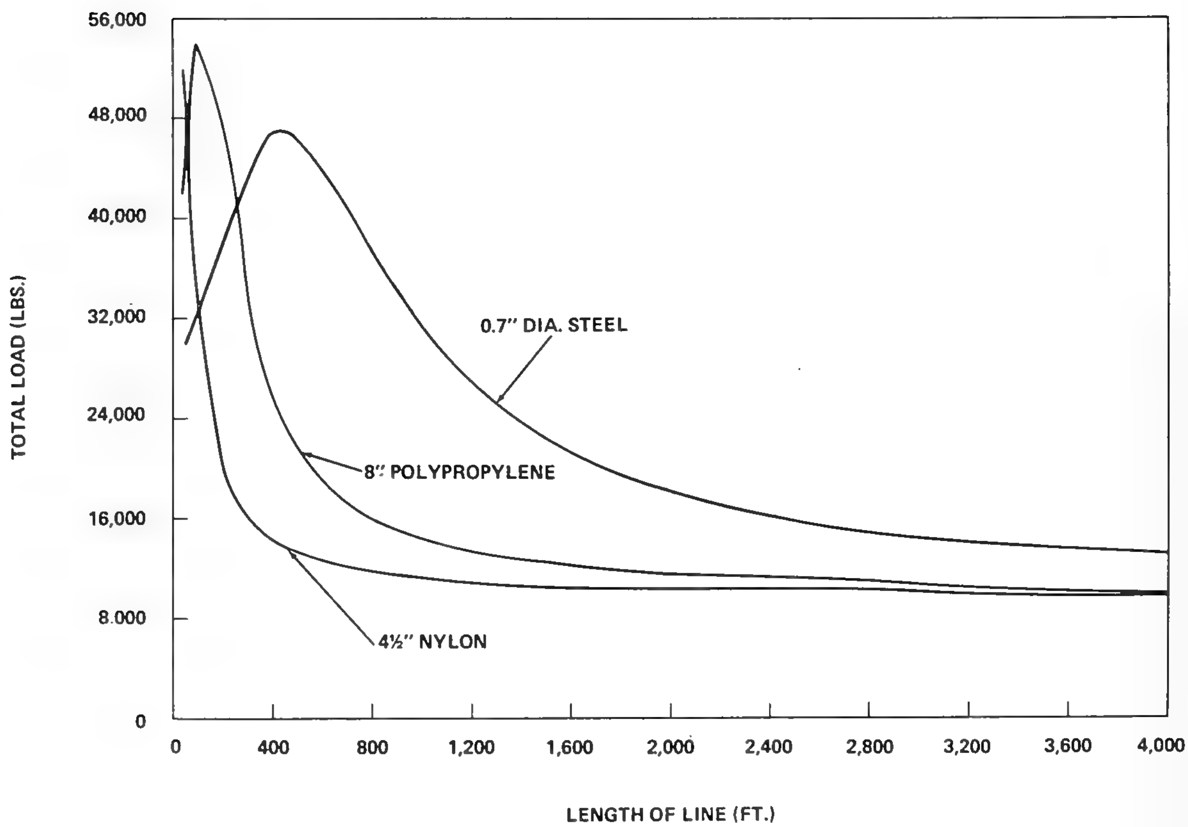
D-8. Total Line Load When $U_O = 2$ and $T = 5$.



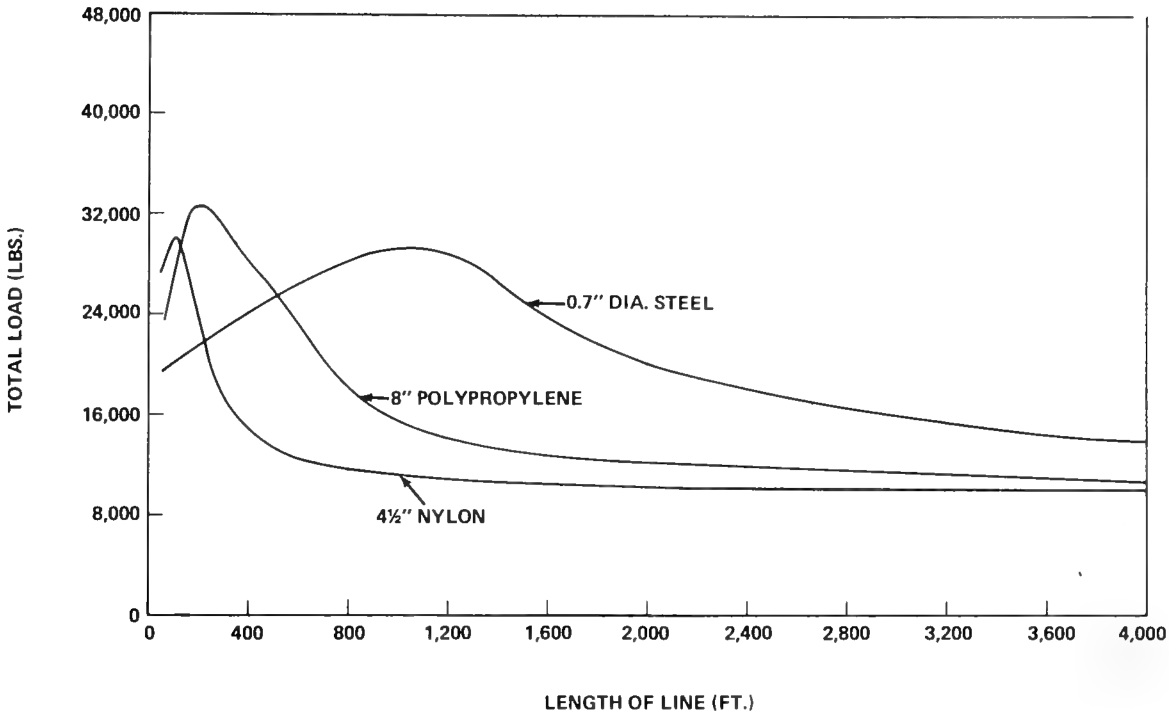
D-9. Total Line Load When $U_O = 2$ and $T = 7$.



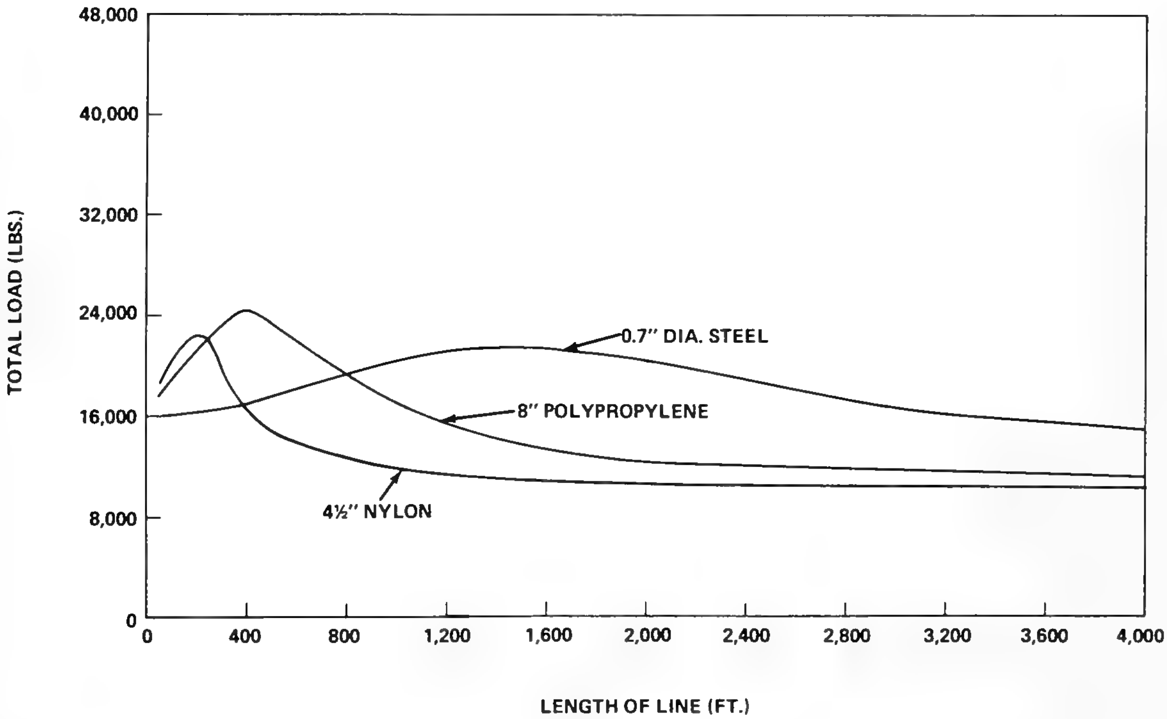
D-10. Total Line Load When $U_O = 2$ and $T = 9$.



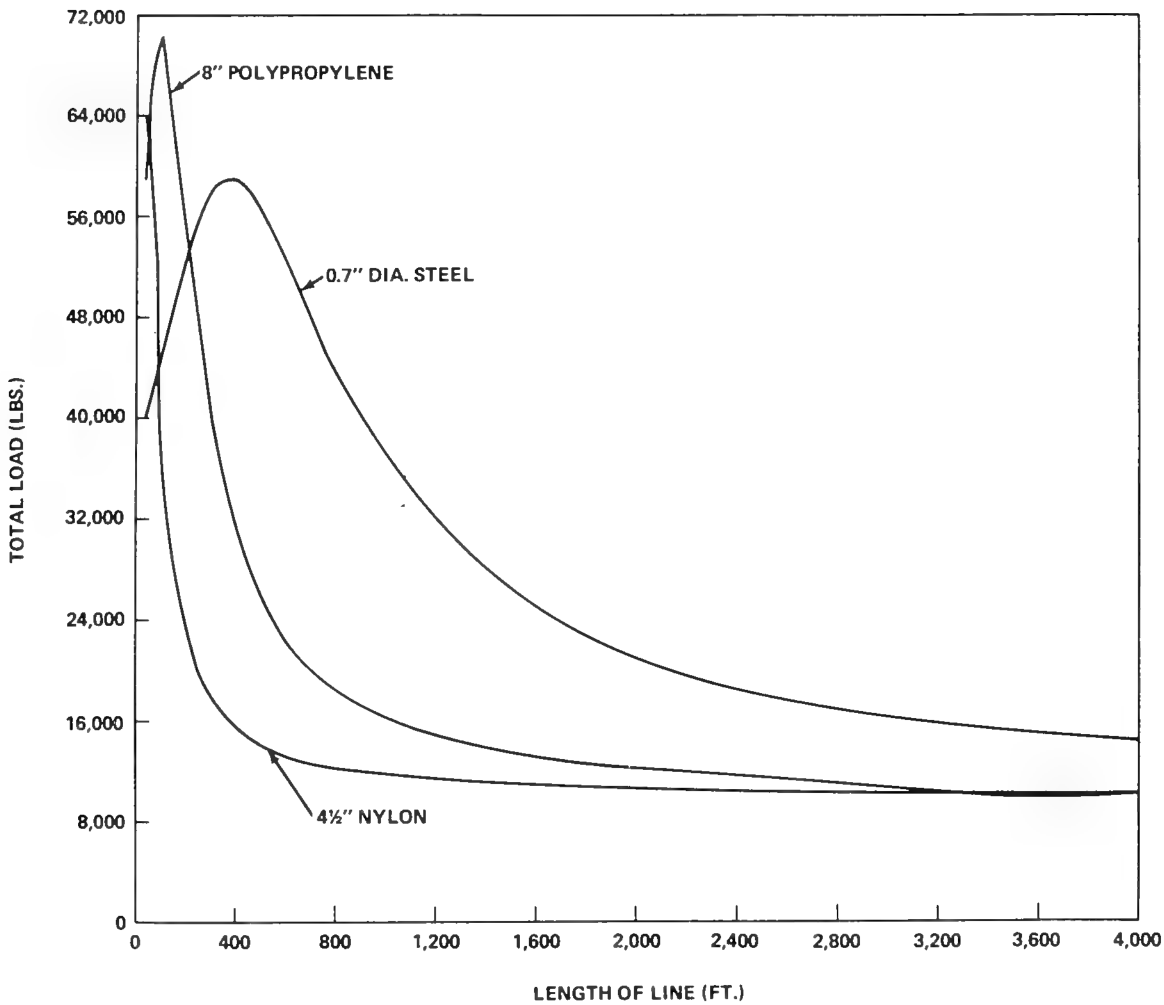
D-11. Total Line Load When $U_O = 5$ and $T = 5$.



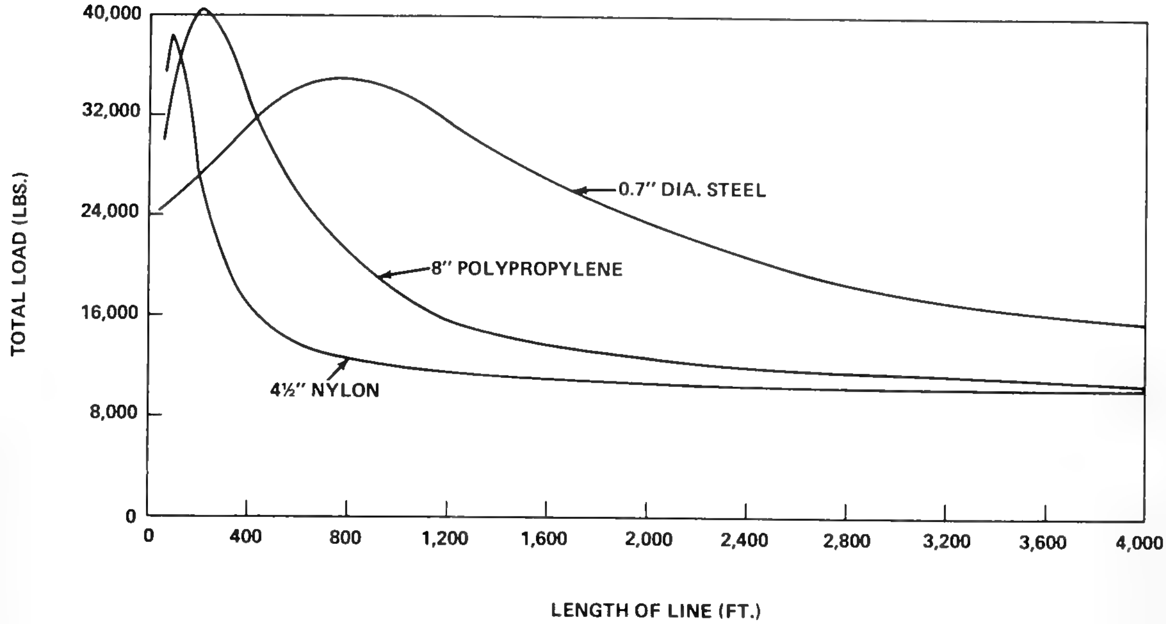
D-12. Total Line Load When $U_O = 5$ and $T = 7$.



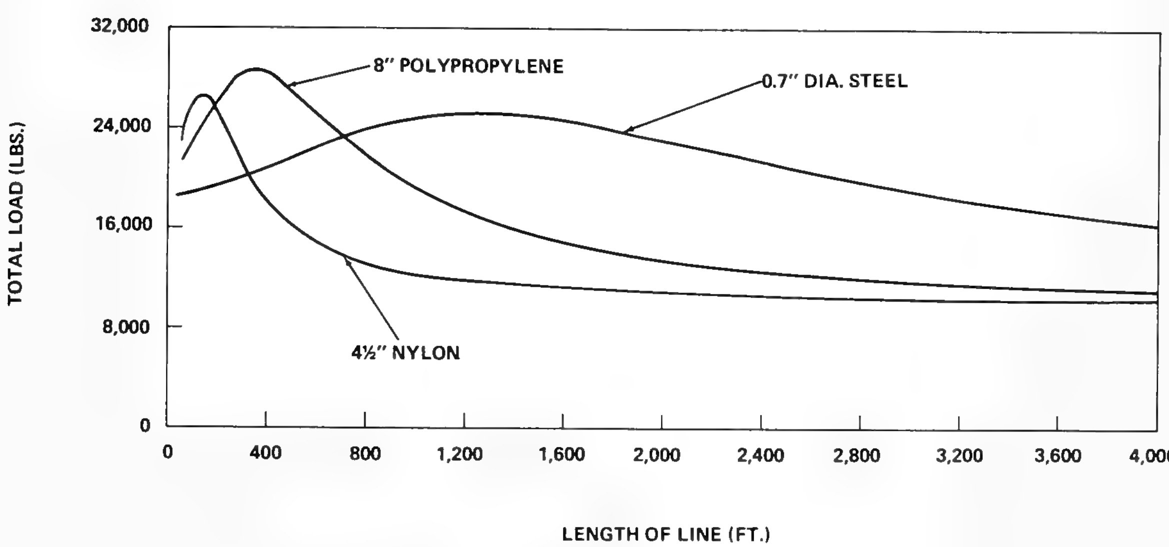
D-13. Total Line Load When $U_O = 5$ and $T = 9$.



D-14. Total Line Load When $U_o = 7$ and $T = 5$.



D-15. Total Line Load When $U_O = 7$ and $T = 7$.



D-16. Total Line Load When $U_O = 7$ and $T = 9$.

APPENDIX E

SALVAGE CORRESPONDENCE

R 221932Z Jul 69

FM NAVSHIPSYSCOMHQ
TO OCEAN SYSTEMS INC 11440 ISAAC NEWTON INDUSTRIAL SQUARE NORTH, RESTON, VIRGINIA 22070

INFO NAVXDIVINGU
NRL
OCEANOGRAPHIC INSTITUTE WOODS HOLE MASS

UNCLAS
ALVIN SALVAGE OPS

1. SUPERVISOR OF SALVAGE US NAVY SENDS. ALL FOLLOWING CONFIRMS PHONECON THIS DATE BY MY MR LAWRENCE TO YOUR MR KUTZLEB.

2. OCEAN SYSTEMS,INC IS TASKED TO PROVIDE ALUMINAUT AND ITS SUPPORT SHIP OCEANIC FOR THE ABOVE OPERATION. BOTH ARE DESIRED AT WOODS HOLE OCEANOGRAPHIC INSTITUTE ON OR BEFORE 4 AUG.

R 221933Z JUL 69

FM NAVSHIPSYSCOMHQ
TO NRL

INFO WOODS HOLE OCEANOGRAPHIC INSTITUTION, WOODS HOLE, MASS. 02543
NAVOCEANO
COMSERVLANT
ONR
CNO
CNM
NAVXDIVINGU

UNCLAS
ALVIN SALVOPS

A. PHONECON MY LAWRENCE YOUR BUCHANAN OF 18 JUL AND 22 JUL

1. SUPERVISOR OF SALVAGE, U.S. NAVY SENDS; ALL FOLLOWING CONFIRMS REFERENCE A.

2. REQUEST OPERATIONAL CONTROL OF USNS MIZAR BE PASSED THIS OFFICE FOR PERIOD OF SUBJECT OPERATION.

3. MIZAR ASSISTANCE TO THIS EFFORT WILL BE REQUIRED FOR APPROXIMATELY FOURTEEN DAYS AND WILL INCLUDE:

A. SUPPORT DRV ALUMINAUT IN SEARCH AND LOCATION OF ALVIN

B. PROVIDE LIFT CAPABILITY FOR RAISING ALVIN

AS A FIRM DETAILED PLAN IS DEVELOPED USNS MIZAR WILL BE INFORMED.

4. IT IS DESIRED USNS MIZAR BE DIRECTED TO BE DOCK SIDE AT WOODS HOLE OCEANOGRAPHIC INSTITUTE (WHOI) ON 1 AUGUST FOR FITTING OUT AND TRAINING. SHIFT OF OPERATIONAL COMMAND IS DESIRED UPON HER ARRIVAL.

5. FOR INFORMATION THE DESIGNATED SUPSALVREP AND OPERATIONAL COMMANDER THIS SEARCH/RECOVERY EFFORT IS LCDR W.I. MILWEE, U.S. NAVY. MY WASHINGTON, D.C. PROJECT MANAGER THIS EFFORT IS MR. EARL F. LAWRENCE, PHONE: WORK (202) 696-3084, HOME (703) 528-4694.

6. AN INITIAL PLANNING MEETING WILL BE HELD WHOI 1000, 23 JUL. REQ NRL REP ATTEND.

R 260116Z JUL 69

FM NRL WASHDC
TO NAVSHIPSYSCOMHQ

INFO COMSTS
COMSTSLANT
USNS MIZAR
NAVOCEANO
COMSERVLANT
CNO
ONR
CNM
NAVXDIVINGU
WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE MASS

UNCLAS
ALVIN SALVOPS
A. YOUR 221933Z JUL 69 (NOTAL)

1. REFERENCE A REQUESTS USE OF USNS MIZAR FOR SALVAGING ALVIN.

2. A PRELIMINARY STUDY OF THIS PROBLEM INDICATES THAT UNCONTROLLABLE RESONANCES MUST BE EXPECTED AT SHORT LINE LENGTHS AND MAY ALSO BE PRESENT NEAR MAXIMUM DEPTH.

3. IT IS OUR OPINION THAT USE OF THE EQUIPMENT AND FACILITIES WHICH ARE NOW AVAILABLE FOR THIS PURPOSE INVOLVE UNACCEPTABLE RISKS.

4. IN ABSENCE OF A COMPLETE STUDY OF DYNAMIC FORCES, RECOMMEND AGAINST EMPLOYMENT OF RECOVERY SYSTEMS CONSIDERED TO DATE.

5. USNS MIZAR SAILING WILL BE DELAYED UNTIL 30 JULY PENDING RESOLUTION OF THESE UNCERTAINTIES. DELAY BEYOND 30 JULY WILL PRECLUDE MEETING PRESENTLY SCHEDULED NRL COMMITMENTS.

P 311710Z JUL 69

FM NAVSHIPSYSCOMHQ
TO NRL

INFO COMSTS
COMSTSLANT
USNS MIZAR
NAVSHIPYD BSN
NAVOCEANO
COMSERVLANT
CNO
ONR
CNM
NAVXDIVINGU
WOODS HOLE OCEANOGRAPHIC INSTITUTE
SUPSHIP THREE

UNCLAS
DRV ALVIN SALVOPS

A. NRL MSG 260116Z JUL 69

1. SUPERVISOR OF SALVAGE U.S. NAVY (SUPSALV) SENDS. SUPSHIP THREE PASS TO ASSTSUPSALV NYK.

2. CONCUR ANALYSIS OF STUDIES DYNAMIC RESPONSE PROPOSED HANDLING OVERSIDE INDICATES RISK OF EXCESSIVE LINE TENSION EXIST.

3. HANDLING THROUGH CENTERWELL FEASIBLE. STUDY DYNAMIC RESPONSE INDICATES ACCEPTABLE LINE TENSIONS UNDER ALL LENGTHS AND CONDITIONS.

4. INSPECTION OF USNS MIZAR ON 29 JULY SHOWED RIGGING AND FAIRLEADS CAN BE INSTALLED TO HANDLE 4 1/2-INCH NYLON LINE THROUGH CENTER WELL.

5. ALL MATERIAL FOR ABOVE WILL BE AVAILABLE AT BOSTON NAVSHIPYD. WORK REQUEST AND FUNDS HAVE BEEN PROVIDED TO BOSTON NAVSHIPYD.

R 061817Z AUG 69

FM ONR WASH
TO NAVSHIPSYSCOMHQ

INFO CNO
CNM
CINCLANTFLT
COMSUBLANT
OCEANAV
COMSERVLANT
COMSTSLANT
NRL
NAVXDIVINGU
WOODS HOLE OCEANOGRAPHIC INSTITUTION

UNCLAS EFTO
NAVSHIPS FOR SHIPS OOC
ALVIN SALVOPS

A. SUPSALV SALVAGE PLAN DATED 4 AUG 69 NOTAL
B. OPNAVINST 4740.2B

1. REF (A) REVIEWED AND CONCURRED WITH.

2. REQ SUPSALV ASSUME SALVAGE RESPONSIBILITY IAW REF B AND PROCEED WITH RECOVERY.

3. REQN TRANSFERRING INITIAL PAYMENT BEING FORWARDED.

P 121710Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP ONE

1. LCDR MILWEE SENDS.

2. COMPLETION OF NAVSHIPYD WORK AT 121035Q VICE 112400Q DELAYED SAILING OF MIZAR ON HOUR FOR HOUR BASIS.

3. USNS MIZAR UNDERWAY FOR SALVAGE SITE AT 121136Q. WILL COMMENCE SEARCH UPON ARRIVAL ABOUT 130400Q.

4. ALUMINAUT UNDERWAY BY 121600Q FOR DRESS REHEARSAL IN PROVINCETOWN HARBOR THENCE TO SALVAGE SITE. FIRST ALUMINAUT DIVE ON BEST DATUM SKED MORNING OF 15 AUG.

5. WEATHER FORECAST FOR OP AREA POSSIBLE GALE WINDS AND VERY ROUGH SEAS.

P 132310Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP TWO

1. LCDR MILWEE SENDS.

2. USNS MIZAR ARRIVED SALVAGE SITE 130400Q AUG AND COMMENCED BATHYMETRIC RUNS. UPON COMPLETION BEGAN FIRST TEN HOUR CAMERA RUN AT 1043Q.

3. STACEY TIDE WITH ALUMINAUT IN TOW UNDERWAY FROM BOSTON 121940Q AUG. FOG DELAYED ARRIVAL PROVICETOWN UNTIL 131100Q. UNABLE TO SATISFACTORILY FIT REEL USING FLOTATION ARRANGEMENT IN HAND. CONSIDER REHEARSAL WITH TOGGLE BAR AND SATISFACTORY HANDLING ARRANGEMENT MANDATORY. HAVE ALLOWED ALUMINAUT FINAL 24 HOUR DELAY WITH ARRIVAL ON SCENE NLT FIRST LIGHT SATURDAY. FURTHER DELAY UNACCEPTABLE BECAUSE OF OP AREA WEATHER AND USNS MIZAR SKED.

4. WEATHER IN OP AREA CURRENTLY IDEAL. FCST FAVORABLE.

P 150025Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP THREE

1. LCDR MILWEE SENDS.

2. RESULTS FROM FIRST TWO CAMERA RUNS BY USNS MIZAR NEGATIVE. THIRD DELAYED BY EQUIPMENT DIFFICULTIES. ANTICIPATE MAXIMUM OF FIVE CAMERA RUNS PRIOR TO ARRIVAL OF ALUMINAUT. IF ALVIN NOT LOCATED BY USNS MIZAR WHEN ALUMINAUT READY TO DIVE INTEND DIVE ALUMINAUT FOR SEARCH ABOUT BEST ESTIMATED POSITION.

3. ALUMINAUT REEL HANDLING DIFFICULTIES UNDER CONTROL. ALUMINAUT TO SAIL FROM PROVINCETOWN ABOUT 150000Z TO ARRIVE SALVAGE SITE SATURDAY MORNING IN READY TO DIVE CONDITION.

4. WEATHER CONTINUES FAVORABLE.

P 152355Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP FOUR

1. LCDR MILWEE SENDS.

2. ONE PHOTOGRAPH OF ALVIN OBTAINED DURING THIRD CAMERA RUN. FOURTH AND FIFTH RUNS MADE FOR VERIFICATION AND ADDITIONAL INFO.

3. CRAWFORD AND ALUMINAUT ENROUTE SALVAGE SITE. CRAWFORD ETA 160600Q AUG. ALUMINAUT DELAYED PROVINCETOWN UNTIL 150300Q. PROCEEDING AT FIVE KNOTS. ETA EARLY SATURDAY AFTERNOON. FOUR HOURS PREPARATION FOR DIVE REQUIRED. INTEND NIGHT DIVE TO FIT LIFTING BRIDLE.

4. INTEND START RIGGING FOR LIFT ABOARD USNS MIZAR SATURDAY MORNING.

5. WEATHER DETERIORATING SLIGHTLY. EXPECT SUITABLE WEATHER FOR OPERATIONS.

P 170120Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP FIVE

1. LCDR MILWEE SENDS.

2. ADDITIONAL PHOTOGRAPHS OBTAINED FOURTH AND FIFTH CAMERA RUNS BY USNS MIZAR GIVE NO SIGNIFICANT ADDITIONAL INFORMATION.

3. ALL UNITS AT SALVAGE SITE, ALUMINAUT ARRIVING ABOUT 161900Q AND COMMENCED SIX HOUR RIGGING JOB. WEATHER MAY PROLONG RIGGING OPERATION. IMMEDIATELY UPON COMPLETION OF RIGGING INTEND MAKE DIVE TO PLACE LIFTING BRIDLE.

4. COMPLETED RIGGING ABOARD USNS MIZAR.

5. WEATHER CONTINUED TO DETERIORATE, WIND 18 TO 20 KNOTS, SEAS FOUR FEET, SWELL DEEPENING.

P 172320Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP SIX

1. LCDR MILWEE SENDS.

2. RIGGING OF ALUMINAUT SECURED AT ABOUT 162300Q BECAUSE COMBINED HAZARDS OF DARKNESS AND ROUGH SEAS PRESENTED UNACCEPTABLY DANGEROUS CONDITIONS. RIGGING RESUMED FIRST LIGHT. DAMAGE SUSTAINED BY LINE REEL AND ALUMINAUT REEL SUPPORT BRACKET DURING RIGGING ATTEMPT NECESSITATED MODIFICATION OF SALVAGE PLANS SUNDAY AFTERNOON.

3. INTEND USE FOUR AND ONE HALF INCH COLUMBIAN PLIMOOR HUNG FROM SURFACE AS PRIMARY LIFTING LINE. LIFTING BRIDLE COMPONENTS TO BE STAYED OFF ON LIFT LINE AND CARRIED TO ALVIN AND PLACED BY ALUMINAUT. RIGGING OF LIFT LINE UNDERWAY ABOARD USNS MIZAR. ALUMINAUT PREPARING FOR DIVE. IN VIEW ANTICIPATED WORSENING WEATHER AND EFFECTS FROM HURRICANE CAMILLE INTEND ROUND THE CLOCK OPERATION THROUGH RIGGING, LIFT AND TOW.

4. WINDS NOW 20-25 KNOTS, SEAS 5-6 FT BUILDING SLIGHTLY.

P 182335Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP SEVEN

1. LCDR MILWEE SENDS.

2. SOME DELAYS ENCOUNTERED BECAUSE OF RIGGING AND EQUIPMENT DIFFICULTIES. AT 181856Q USNS MIZAR AND NRL TRACKING TEAM SUCCEEDED IN PLACING CLUMP WITHIN ONE HUNDRED YARDS OF ALVIN WRECK.

3. PROCEEDING TO PASS LIFT LINE TO BUOY. ALUMINAUT STANDING BY TO DIVE AS SOON AS LIFT LINE IS CAST OFF.

4. WEATHER REMAINS STABLE.

P 192305Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

INFO COMSTSLANT

UNCLAS
ALVIN SALVOPS SITREP EIGHT

1. LCDR MILWEE SENDS.

2. ALUMINAUT DIVED 182005Q LOCATED AND INSPECTED ALVIN. FOUND LOWER HATCH OPEN, MANIPULATOR ON, AND FOREBODY SECURE TO AFTER-BODY. LOCATED CLUMP AND DEPLOYED TOGGLE. UNABLE TO INSERT TOGGLE IN HATCH. SURFACED AT 190830Q AFTER EXPENDING ALL BATTERY AND LIFE SUPPORT SYSTEM ENDURANCE. DURING DIVE ALUMINAUT SUFFERED CASUALTIES TO STRAZA SONAR, VERTICAL MOTION MOTOR AND MANIPULATOR WHICH INHIBITED SEARCH AND TOGGLE BAR EMPLACEMENT. HEAVY SEAS PREVENTED CONDUCTING BATTERY CHARGE FOR SECOND DIVE. MOISTURE IN SUBMARINE CAUSED NUMEROUS GROUNDS THROUGHOUT ELECTRICAL SYSTEM.

3. IN VIEW NUMEROUS CASUALTIES SERIOUSLY REDUCING ALUMINAUT EFFECTIVENESS AND WORSENING WEATHER IN OPAREA HAVE TEMPORARILY SUSPENDED SALVAGE OPERATIONS AND AM PROCEEDING INTO WOODS HOLE. CONSIDER PROBABILITY OF SUCCESS WITH PROPERLY OPERATING SUBMARINE VERY HIGH.

P 211500Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP NINE

1. LCDR MILWEE SENDS.

2. ALL UNITS IN WOODS HOLE. REPAIRS UNDERWAY ON ALUMINAUT STRAZA SONAR AND VERTICAL PROPULSION MOTOR. ALL NECESSARY MATERIAL ON HAND. ETC ALUMINAUT REPAIRS FRIDAY AFTERNOON. INTEND ALUMINAUT UNDERWAY FOR SALVAGE SITE UPON COMPLETION OF REPAIRS, OTHER UNITS AFTERWARDS TO ARRIVE SITE SIMULTANEOUSLY.

P 241502Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP TEN

1. LCDR MILWEE SENDS.

2. MANIPULATOR DIFFICULTIES NECESSITATED ALUMINAUT BEING REMOVED FROM WATER.DECISION TO HAUL OUT AT NEW BEDFORD CHANGED DUE TO MARGINAL SAFETY OF ONLY AVAILABLE MARINE RAILWAY. ALUMINAUT NOW AT BOSTON NAVAL SHIPYARD LIFTED OUT OF WATER.

3. MANIPULATOR MOTOR REPAIRS SATISFACTORILY COMPLETED. FIT UP OF TOGGLE BAR IN PROGRESS ETC 242400Q.

4. EXPECT ALUMINAUT UNDERWAY UPON COMPLETION OF REPAIRS REACH SITE WEE HOURS WEDNESDAY. USNS MIZAR AND CRAWFORD TO SAIL MONDAY NIGHT FOR RENDEZVOUS AT SITE AND RECOVERY OF ALVIN.

P 271330Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP ELEVEN

1. LCDR MILWEE SENDS.

2. STACEY TIDE UNDERWAY FOR SALVAGE SITE 25 AUG, USNS MIZAR AND CRAWFORD UNDERWAY 26 AUG FOR WEDNESDAY MORNING RENDEZVOUS.

3. STACEY TIDE STANDING BY BUOY LEFT AT SITE AT 270600Q. ALUMINAUT BEING PREPARED FOR DIVE COMMENCING WEDNESDAY AFTERNOON.

4. WEATHER SATISFACTORY FOR OPERATIONS. SEAS 3-5 FT WIND 15-20 KTS.

P 281250Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP TWELVE

1. LCDR MILWEE SENDS.

2. ALUMINAUT SUBMERGED AT 271323Q AUG AND AFTER FOURTEEN HOURS OF HERCULEAN EFFORT IN WHICH NUMEROUS DIFFICULTIES WERE ENCOUNTERED AND OVERCOME SUCCEEDED IN FIRMLY IMPLANTING THE TOGGLE BAR IN ALVINS HATCH AND SUBSEQUENTLY SECURING THE TOGGLE BAR PENDANT TO THE MAIN LIFT LINE. ALUMINAUT SURFACED 280615Q AUG AFTER A DIVE OF NEARLY SEVENTEEN HOURS. A SPLENDID PERFORMANCE BY ALUMINAUT AND HER CREW.

3. TRANSFER OF MAIN LIFT SYSTEM FROM BUOY TO USNS MIZAR LIFT SYSTEM IN PROGRESS. INTEND TO MAKE LIFT ON TOGGLE BAR ONLY.

4. WEATHER MODERATING SEAS 1-2 FT WIND 8-10 KTS.

P 291250Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP THIRTEEN

1. LCDR MILWEE SENDS.

2. TRANSFERRED MAIN LIFT LINE TO USNS MIZAR MAIN LIFT SYSTEM AND LIFTED ALVIN TO WITHIN ONE HUNDRED FEET OF SURFACE AND CAPTURED ON NORMAL LIFTING BRIDLE. BECAUSE OF IDEAL WEATHER CONDITIONS EXTANT IN THE OPAREA ATTEMPTED TO FLOAT ALVIN FOR SURFACE RATHER THAN SUBMERGED TOW TO WOODS HOLE. DUE TO LEAKY BALLAST TANKS AND JAMMED TOGGLE BAR WHICH PREVENTED INSERTION OF PUMP SUCTION HOSE IN PRESSURE SPHERE UNABLE TO OBTAIN ADEQUATE BUOYANCY FOR FLOTATION. WRAPPED ALVIN IN A NET AND SUSPENDED BENEATH THREE 8.4-TON SALVAGE PONTOONS FOR TOW TO VINEYARD SOUND AREA. TOW UNDERWAY 290220Q AUG WITH SOA OF TWO KNOTS. ETA VINEYARD SOUND EARLY SUNDAY MORNING.

3. ALVIN APPEARS ESSENTIALLY INTACT. DAMAGE CONFINED PRIMARILY TO FIBERGLASS FAIRINGS. ALL PROPULSION MOTORS ARE BROKEN OFF BUT ARE SECURELY LASHED TO THE WRECK. MANIPULATOR IS INTACT AND LASHED TO WRECK.

P 292315Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP FOURTEEN

1. LCDR MILWEE SENDS.

2. CONTINUED TOW OF ALVIN TOWARD VINEYARD SOUND. ACTUAL SOA SLIGHTY LESS THAN TWO KNOTS. ETA VINEYARD SOUND SUNDAY AFTERNOON. DIVERS INSPECTION OF TOW REVEAL TOW TO BE IN GOOD CONDITION AND TOWING SATISFACTORILY.

3. RELEASED ALUMINAUT ABOUT 291330Q AFTER CROSSING FIFTY FATHOM CURVE. ALUMINAUT PROCEEDING TO BOSTON NAVSHIPYD.

4. WEATHER FRESHENING SLIGHTLY BUT REMAINS EXCELLENT.

P 302310Z AUG 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

UNCLAS
ALVIN SALVOPS SITREP FIFTEEN

1. LCDR MILWEE SENDS.

2. CONTINUED TOW OF ALVIN TOWARDS VINEYARD SOUND ETA REMAINS LATE SUNDAY AFTERNOON. DURING EARLY MORNING HOURS OF 30 AUG ONE PONTOON BECAME DEFLATED AND SECOND BEGAN TO LOSE AIR. RIGGED ADDITIONAL PONTOON TO TOW AND HAVE TWO MORE STANDING BY ON DECK. TOW RIDING WELL.

3. ARRANGEMENTS COMPLETED FOR LIFT OUT BY CRANE AND BARGE MONDAY MORNING. INTEND FORMAL TURNOVER OF WRECK TO WHOI PERSONNEL WHEN WRECK HAS BEEN LANDED AND SECURED ON BARGE.

P 010015Z SEP 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

INFO COMSTSLANT

UNCLAS
ALVIN SALVOPS SITREP 16

1. LCDR MILWEE SENDS

2. USNS MIZAR ANCHORED IN MENEMSHA BIGHT AND PREPARED ALVIN FOR FINAL LIFT. ALL PREPARATIONS COMPLETE FOR LIFT MONDAY.

P 011455Z SEP 69

FM USNS MIZAR
TO NAVSHIPSYSCOMHQ (SUPSALV)
ONR WASHDC

INFO COMSTSLANT

UNCLAS
ALVIN SALVOPS SITREP 17 AND FINAL

1. LCDR MILWEE SENDS.

2. ALVIN LIFTED ABOARD BARGE IN VINEYARD SOUND FOR DELIVERY TO WHOI.

3. USNS MIZAR DETACHED TO PROCEED TO WASH DC TO OFFLOAD EQUIP. CRAWFORD DETACHED TO PROCEED TO WOODS HOLE. SALVOPS COMPLETED.

APPENDIX F

COMMAND AND ADMINISTRATION

The following organizations and their personnel contributed to the successful recovery of ALVIN. An organizational chart of the recovery operation is given in Figure F-1.

Supervisor of Salvage, USN	
Supervisor of Salvage	CAPT E. B. Mitchell, USN
On-Scene Commander	LCDR W. I. Milwee, Jr., USN
Salvage Master	Mr. E. F. Lawrence
Woods Hole Oceanographic Institution	S. Daubin
	W. O. Rainnie, Jr.
	A. Eliason
	W. M. Marquet
	R. G. Graham
	A. F. Medeiros
	F. Omohondro
	M. McCamis
	C. Winget
Ocean Systems, Inc.	F. W. Hobbs
	R. Kutzleb
Reynolds Submarine Services	C. Morris
	R. Canary
Naval Underwater Weapons Research and Engineering Station, Newport	
Diving Team	BMCS (DV) M. Oranczak, USN
	MM1 (DV) G. A. Landrum, USN
	DC1 (DV) R. F. Ottinger, USN

Naval Research Laboratory	C. L. Buchanan R. Bridge J. D. Clamons L. S. Greenfield D. E. Shirley G. Worthington J. J. Gennari E. W. Carey R. B. Patterson J. Campbell G. J. Gant E. Czul
Office of Naval Research	LCDR. J. D. Donnelly, USN
Submarine Development Group One	LCDR J. R. Finlen, USN
Boston Naval Shipyard	CAPT R. C. Gooding, USN
U. S. Coast Guard Underwater Safety	LT H. T. Suzuki, USCG
Military Sea Transportation Service USNS MIZAR	CAPT C. A. Reichert, MSTS
Potomac Research, Incorporated	L. Campomenosi E. Bain
Commandant 1st Naval District Public Affairs	CDR M. Romano, USN J. Harrington
Naval Ship Systems Command Public Affairs	S. Harrison
Battelle Memorial Institute	D. Hackman
MAR-LOR Crane Rental Service	D. Clark

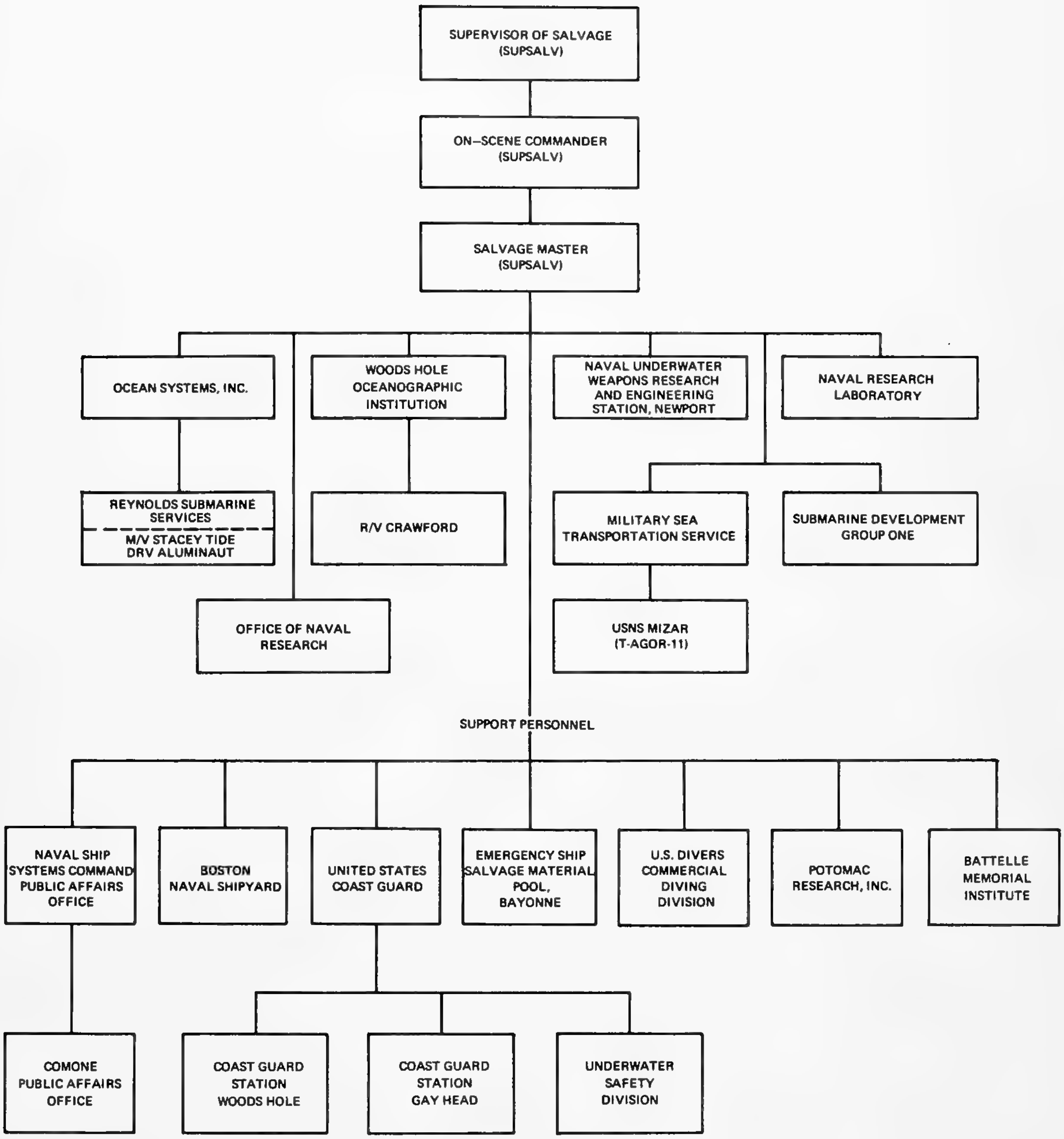


Figure F-1. Organizational Chart.

APPENDIX G

NAVIGATION PLANS

NAVIGATION PLAN "A"

Sequence of Operations (See figure G-1)

1. MIZAR arrives on station using Loran A and/or other surface navigation aids.

2. MIZAR conducts local area bathymetry survey to establish best estimate of ALVIN location. Bottom marker No. 1 is dropped as near ALVIN as possible (accuracy goal is 300-400 yards).

3. MIZAR stays on station using her three-dimensional computer system.

4. MIZAR tracks ALUMINAUT on the surface with radar.

5. MIZAR talks ALUMINAUT into position over marker No. 1.

6. ALUMINAUT dives to bottom. MIZAR tracks ALUMINAUT during descent.

7. ALUMINAUT is given courses to steer to home in on marker No. 1.

8. ALUMINAUT conducts CTFM sonar search for ALVIN. During this search she uses the CTFM transponder as a local navigation bottom reference. The surface also tracks ALUMINAUT. Depth contours will be a valuable guide.

9. ALUMINAUT finds ALVIN and her position relative to marker No. 1 is recorded.

Failure Mode Reactions for Navigation Plan "A"

1. If AMF transponder on marker No. 1 nearest ALVIN fails, call it back and set another.

2. If the CTFM transponder on marker No. 1 fails, continue with ALUMINAUT search using surface tracking navigation. Set another if required.

3. If the CTFM sonar on ALUMINAUT fails and if ALUMINAUT is on the bottom, continue with a visual search using surface tracking navigation. Repair ALUMINAUT's CTFM sonar. Install WHOI backup SM500 CTFM sonar.

4. If MIZAR's computer tracking fails, shift to Navigation Plan "B".

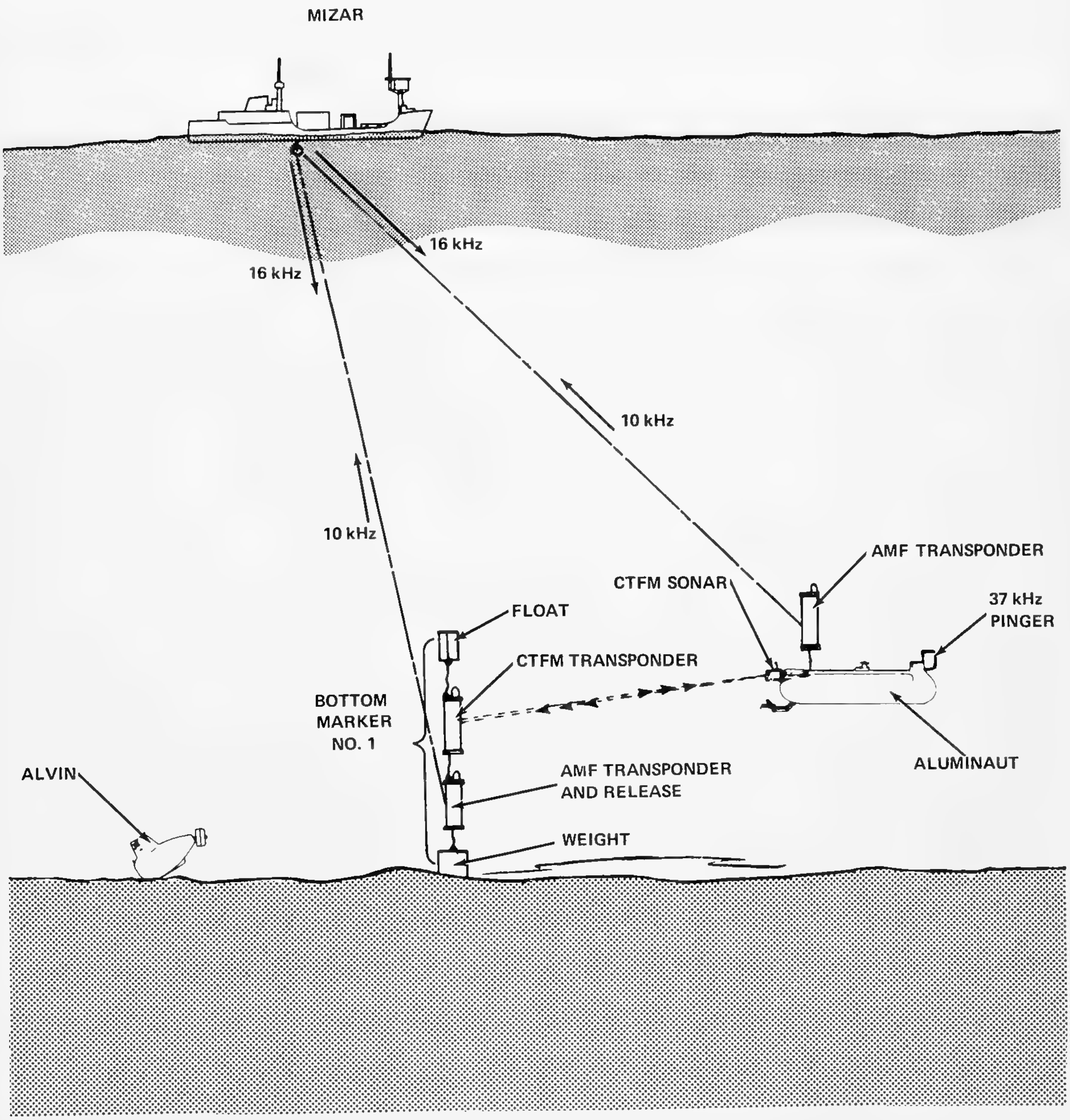


Figure G-1. Navigation Plan "A".

NAVIGATION PLAN "B"

General

This backup plan assumes that MIZAR's computer tracking may be inoperative and that the CTFM sonar equipment is working.

Sequence of Operations (See figure G-2)

1. Based on surface navigation and bathymetry, MIZAR sets two bottom markers. Marker No. 1 is set as near ALVIN as possible. Marker No. 2 is set at the same depth as No. 1 and about 2,000 yards from No. 1.

2. MIZAR alternately interrogates the two markers and plots her position relative to the markers.

3. MIZAR tracks ALUMINAUT on the surface with radar and talks her into position over marker No. 1.

4. ALUMINAUT dives to the bottom and is tracked by MIZAR.

5. MIZAR plots her position relative to the markers.

6. If necessary MIZAR (who is tracking ALUMINAUT) guides ALUMINAUT toward marker No. 1.

7. ALUMINAUT finds marker No. 1 with her CTFM sonar in transponder mode (maximum range of 800 yards).

8. ALUMINAUT conducts sonar search for ALVIN using the CTFM transponder as a navigation reference.

9. ALUMINAUT finds ALVIN and reports her position relative to the CTFM transponder on marker No. 1.

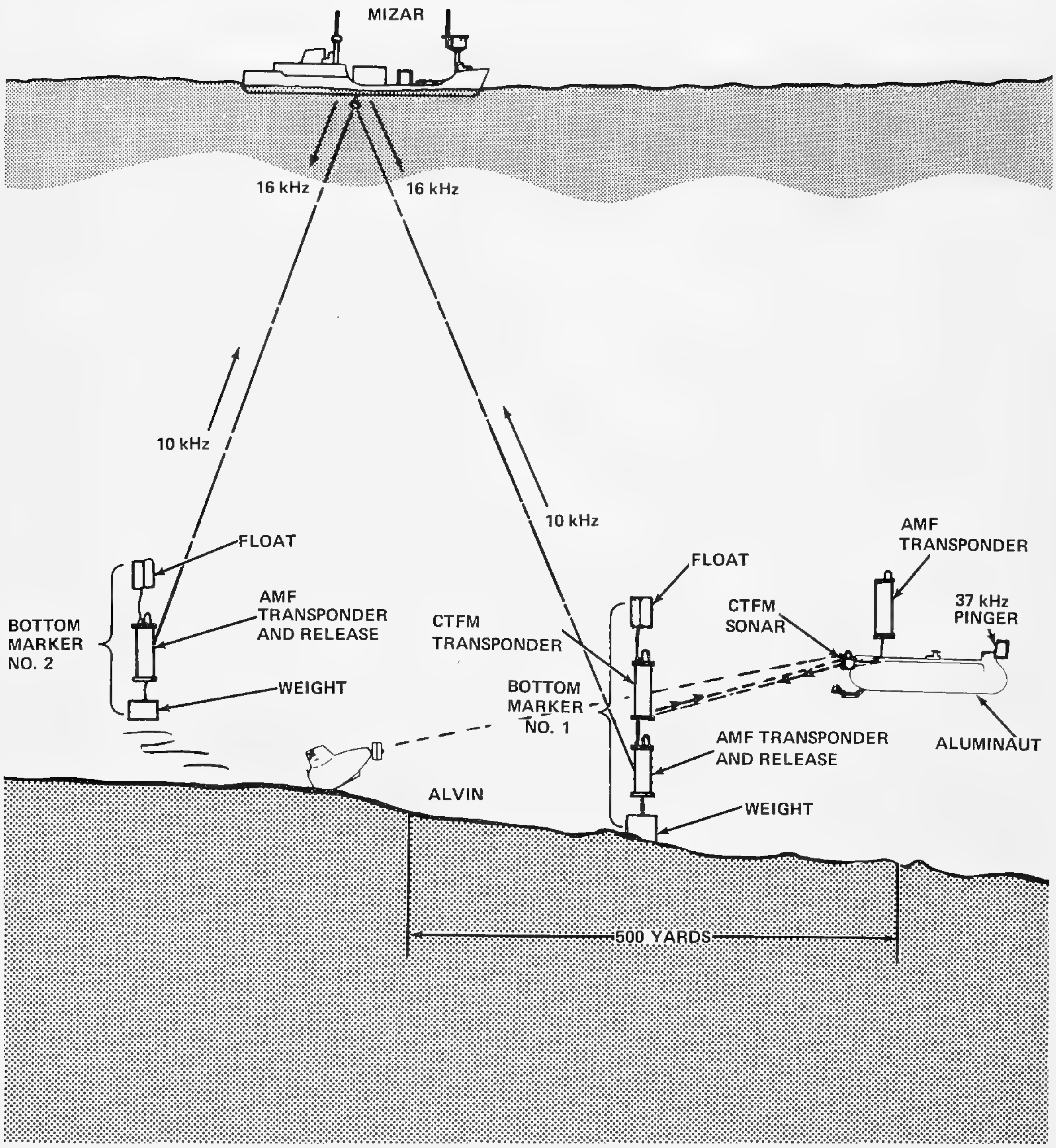


Figure G-2. Navigation Plan "B".

NAVIGATION PLAN FOR BACKUP CLUMP LOWERING PLAN "A"

General

This plan provides the navigation information necessary to position a MIZAR-lowered recovery clump near bottom marker No. 1 which has been moved by ALUMINAUT to a position next to ALVIN.

Method (See figure G-3)

1. ALUMINAUT finds ALVIN and then moves marker No. 1 to a position very near ALVIN. ALUMINAUT departs.
2. MIZAR lowers recovery clump which has an AMF transponder in the line.
3. Using three-dimensional tracking, MIZAR positions the clump near ALVIN.

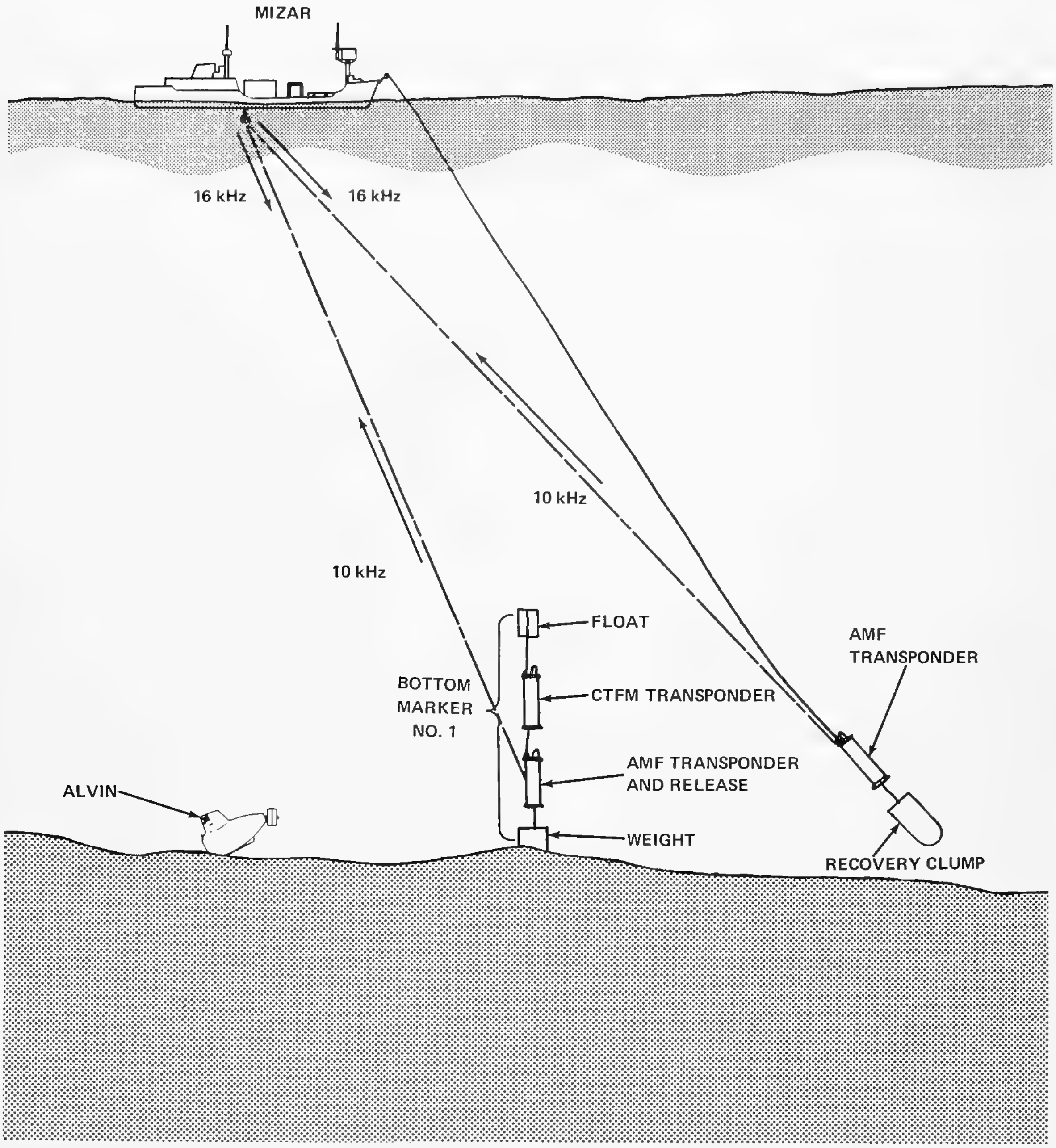


Figure G-3. Navigation Plan for Backup Clump Lowering Plan "A".

NAVIGATION PLAN FOR BACKUP CLUMP LOWERING PLAN "B"

General

This plan provides the navigation information necessary to position a MIZAR-lowered recovery clump near ALVIN if MIZAR's three-dimensional computer tracking equipment is inoperative.

Method (See figure G-4)

1. ALUMINAUT finds ALVIN and moves bottom marker No. 1 to a position very near ALVIN. ALUMINAUT departs.

2. MIZAR plots her position using the AMF transponders on markers No. 1 and No. 2.

3. MIZAR lowers recovery clump which has a modified EDO transponder in the line.

4. MIZAR moves recovery clump near marker No. 1. The time difference between the receipt of the 10 kHz signal from marker No. 1 and the 8 kHz from the EDO transponder is used to indicate the distance of the clump from marker No. 1.

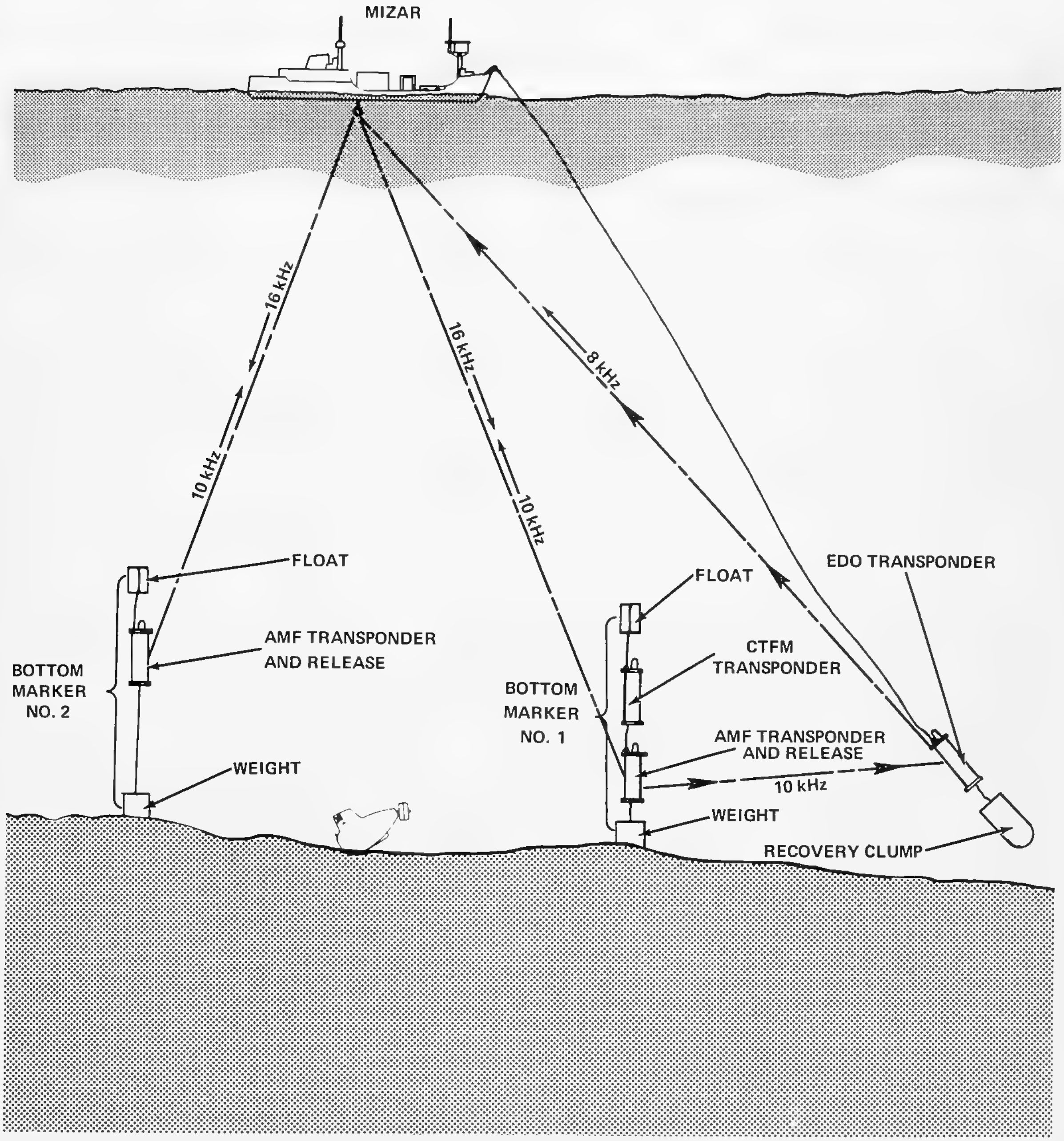


Figure G-4. Navigation Plan for Backup Clump Lowering Plan "B".

APPENDIX H

LIFT LINE LAUNCHING PROCEDURE

The following lift line launching procedure was developed:

1. Run doubled line through eye splice at 18-foot point and reeve through sheave on U-frame.

2. Deploy Stimson anchor and headache balls over side and stop off.

3. Attach cherry picker hook to eye at 18-foot point and take a strain on the line.

4. Install pinger battery and connect up. Test for proper operation. Remove toggle cotter pin.

5. Shackle balls to end of line and take strain with the cherry picker.

6. Burden over to double line through U-frame.

7. When load is all on U-frame, remove hook from eye.

8. Burden main lift line to sheave in center well.

9. Remove lowering line, if possible.

10. If necessary haul in main lift line until 18-foot eye is accessible and cut lowering line free.

11. Raise or lower main lift line until 83-foot eye is accessible from after door of center well.

12. Attach lower end of instrument string to 83-foot eye.

13. Continue to lower main lift line until 134-foot eye comes into view; at the same time deploy instrument string by hand.

14. Attach upper end of instrument string to 134-foot eye.

15. Lower away.

16. Lower carriage to bottom.

17. At beginning of cast-off phase, raise carriage.

18. When splice between main lift line and tag pendant comes into view, cut free of lift line and secure to messenger No. 1.

19. Bring tag pendant to deck via messenger No. 1; secure to lower (forward) end of pontoon which is lashed to gunwhale outboard. Launch pontoon.

20. Lower away and burden weight of main lift line to pontoon.

21. Up-behind on main lift line. When bitter end is in hand attach to messenger No. 2. Cast free in well.

22. Cast off pontoon painter. The lift line is now buoyed free of MIZAR.

APPENDIX I

OUTFITTING AND TESTING OF VESSELS

The following was accomplished at Boston Naval Shipyard for 1969 salvage operations:

1. Ran electrical power cable for traction winch.

2. Designed, fabricated, and installed foundation for traction winch. Installed traction winch and connected electrically.

3. Procured special block with load cell attachment capability.

4. Fabricated four wire pendants for block installation in overhead of center well.

5. Provided calibrated back-up dynamometer.

6. Installed and load-tested four pads in overhead of center well and padeye on foremast to 50,000 pounds.

7. Tested center well lift system simulating actual lift conditions as closely as possible to 20,000 pounds.

8. Made up 85-foot wire pendant (1-inch-diameter) with "hard-eyes" for ALVIN tow pendant.

9. Manufactured new toggle bars to drawings furnished.

10. Unloaded ALUMINAUT from STACEY TIDE and commenced readiness for sea preparations.

11. Put spare lift line (Samson 4 1/2-inch braided nylon) aboard STACEY TIDE.

12. Installed and tested empty reels on ALUMINAUT.

13. Wound line on reels and determined weight of reel and line when immersed in water. Installed each reel and line on ALUMINAUT simulating at-sea loading.

14. Tested toggle in dummy hatch. Tested reels and line for payout and braking.

15. Rehearsed transfer of line to MIZAR, making certain that divers were familiar with procedure.

16. Provided additional rigging gear from salvage pool as needed.

17. Provided other industrial and logistic assistance as required.

RECOVERY OF NAVSHIPS 0994—004—5010

DEEP RESEARCH VEHICLE ALVIN